Adoption of Natural Farming and its Effect on Crop Yield and Farmers' Livelihood in India

The study was carried out with financial support of
NITI Aayog, Government of India
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ICAR-National Academy of Agricultural Research Management
(ISO 9001:2015 CERTIFIED)
Rajendranagar, Hyderabad-500 030, Telangana, India

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Images on Front and Back Cover:

1) Mulching in sugarcane field
2) *Jeevamritha* in barrel
3) Indigenous cow maintained by NF farmer
4) Intercrop in NF field
5) Earthworm in NF soil sample
6) Soil sample collection for lab analysis
7) *Jeevamritha* application in the field
8) *Ghanajeevamritha* used in Andhra Pradesh

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Preface

Natural Farming or Zero Budget Natural Farming (ZBNF) has become a pivot point of discussion among the agricultural scientists, government, farmers, and several other informal groups engaged in agriculture. This is mainly due to the reason that there are two diametrically opposite schools of thought on this topic co-existing in the country. Some scientists straightaway discard the philosophy of Natural Farming. On the other hand, its proponents are claiming the method to be a panacea for all problems causing distress in Indian agriculture, especially for smallholders.

To get the answer to several critical questions, NITI Aayog entrusted the teams at ICAR-NAARM and ICAR-CRIDA to carry out the present study. The study necessitated both primary surveys as well as lab analysis of samples. The primary survey, which included various information related to socio-economic profile, cropping pattern, input use, output marketing, etc. from the Natural Farming adopters as well as Non-adopters was conducted by NAARM-team. At the same time, plant and soil samples from selected fields of the adopter and non-adopter farmers were also collected for lab analysis, which was done by the team at CRIDA.

The study was carried out in the states of Andhra Pradesh, Karnataka and Maharashtra. The students of Andhra University, Vishakhapatnam, Agribusiness Management College, University of Agricultural Sciences, Bengaluru, and Marathwada Agricultural University, Parbhani were engaged for the data collection in the states of Andhra Pradesh, Karnataka and Maharashtra, respectively. The project team is grateful to the concerned colleges, the coordinating faculty, and the students for field survey. We also duly acknowledge the sincere effort of several project staffs at CRIDA & NAARM, especially Mr. Sharath Kumar.

We express our sincere gratitude to Dr. Ch. Srinivasa Rao, Director, ICAR-NAARM for showing keen interest and unconditional support in carrying out the project. We are also thankful to the Director, ICAR-CRIDA for giving all kinds of support in conducting this collaborative study. Most importantly, we sincerely thank all the farmer-respondents who took the time to share their information during the field survey.

We are very much thankful to NITI Aayog, Government of India for entrusting us the study.

We hope the report would answer some of the critical questions about Natural Farming. However, at the same time, it also opens new vistas for research with many key researchable questions that need to be systematically investigated to understand the causality, sustainability, and long-term impact of Natural Farming.

Hyderabad **Project Team**

July 2020

Executive Summary

Agriculture in India has witnessed several technological advancements. 'Green Revolution' (GR) technology-led intensification of agriculture transformed India from food scarce to food surplus country. However, it also led to adverse impacts like soil degradation, biodiversity losses, rising cost of cultivation, etc. Rising application of chemical fertilizers and pesticides with stagnating/declining crop productivity dovetailed with uncertain market conditions and climate change effect resulted in unremunerative agriculture. Consequently, a large number of farmers falling into the debt trap, and distress in farming sector became pervasive. In due course, organic farming started gaining importance. The demand for organic food products is on constant rise worldwide. India exported organic products worth $ 515 million in 2017-18, about 40% higher than the previous year. Currently, 1.78 million hectares of cultivated area is estimated to be under organic farming in India. Though, very high price of organic food products vis-a-vis conventional food makes it inaccessible to low-income population. On the other hand, the need for a large quantity of FYM/organic fertilizers and costly certification processes makes it impossible for small farmers to adopt it.

Natural Farming (NF) or Zero Budget Natural Farming (ZBNF), as commonly known, is purported to be a disruptive farm practice addressing major concerns of farmers of the rising cost of production. It envisages ecological or regenerative agriculture approaches under which the application of any kind of chemicals to soil biosystems are prohibited. It relies more on soil biology than soil chemistry by encouraging multi-cropping, round-the-year soil cover, the addition of formulation made up of cow dung and urine to trigger the microorganisms in the soil system. However, it is being dubbed by the scientific fraternity as an unscientific and hype-created story. Contrary to it, thousands of farmers across the states in India are using one or other components of the NF practices. The proponents and practitioners are confident and upbeat about it, while non-practitioners and scientific community have serious doubts about the claim. Hence, it is imperative to study the adoption of NF practices and their effect on crop choices, crop yield, farm income as well as scalability and sustainability at farmers' fields.

Keeping this in view, the present study sponsored by NITI Aayog has been conducted in three leading states- Andhra Pradesh (largest expansion of ZBNF), Karnataka (first adopted state) and Maharashtra (State with maximum farm distress reported). The field survey was conducted in these states during February- May 2019 and personal interview of adopters and non-adopters of Natural Farming was conducted to understand the perception and realization of the farmers. To supplement the socio-economic findings, samples from the fields (soil, plant and *Jeevamritha*) of NF-adopter and non-adopter were also collected and analyzed at ICAR- Central Research Institute for Dryland Agriculture (CRIDA). Thus, the present study is the first systematic study conducted unravelling several facets of Natural Farming in India.

Salient findings of the study:

Adopter-Farmers following ZBNF/ NF practices

Jeevamritha- ✓✓✓✓ (all)
Beejamritha- ✓✓✓(mostly)
Mulching- ✓ (few)
Mixed/intercrop- ✓✓ (some)
Wapasa- ✗ (rarely)

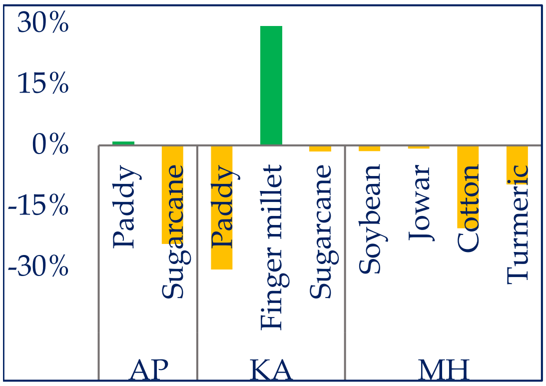
Moderate quantity of FYM was used before sowing in many cases

Worth mentioning!!

- Some famers in Karnataka are practicing NF since past 15 years & are satisfied with its benefits.
- NF produce has potential to attract premium price.
- However, available nutrients in NF field and NF plants are observed to be lower than those in conventional farming.

Crop Yield comparison

- In general, NF has not shown higher yield than conventional farming.
- Finger millet, very low input crop under conventional farming, gave better yield in NF.
- When NF is supplemented with moderate FYM, crop yield improved significantly *(Annex II)*.
- Natural Farming may not be yield enhancing but helped in improving farmers' income by reducing cost of cultivation, and attracting better product price.



Percent change in yield over conventional farming

Benefits perceived by NF adopter-farmers

- Reduced cost of cultivation
- Freedom from chemicals
- Better taste and product quality
- Premium product price
- Better crop during dry spell
- Improved soil quality
- No exposure to pesticide

Perception of non-NF farmers for not adopting NF

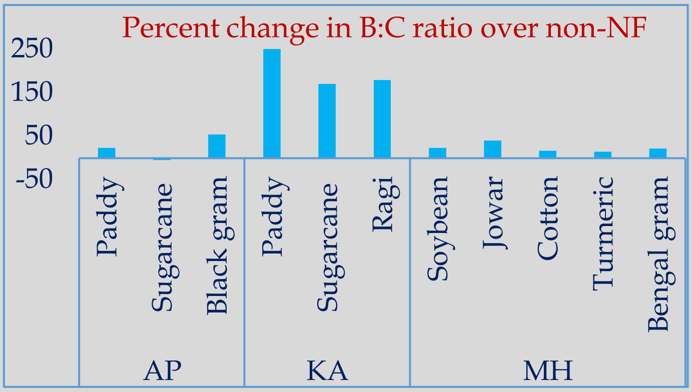
- Non-availability of readymade *Jeevamritha*
- Fear of poor yield
- Not owning indigenous cow
- More engagement in farming
- No gurantee of premium price
- Possibility of crop failure

Plant & Soil Sample Analysis

- Mixed results were found for soil and plant nutrients level as well as soil microbiological counts from lab analysis. Invariably, NF fields exhibited lower level of macro-nutrients.
- With limited comparable samples from fields, it is difficult to compare and conclude the effect of NF on soil and plant nutrient status.

Profitability

B:C ratio is better in NF owing to less input cost and attracting premium price for chemical-free produce



Sustainability and Scalability

- In the long-run, NF may lead to exhaustion of nutrients from soil, if practiced in monocropping.
- NF-farmers perceived it to be climate resilient, less irrigation demanding and improving soil quality.
- NF may not be a substitute for conventional farming for large scale food production. Rather it may be promoted in low-input region for smallholders.
- Institutional arrangement through KVKs & FPOs needed for its promotion and market linkage for premium price for the NF products.

Way forward…

- ✓ Natural Farming practices should be seen as one of the alternative options for the producers & the consumers for chemical-free produce.
- ✓ NF produce be recognized as niche product and may be encouraged through cluster-farming (FPOs) to have better traceability of the produce.
- ✓ Moreover, scientific evidences need to be generated before scaling out in different agro-climatic regions with different crop combinations for its long-term sustainability.

Unanswered questions...

Farmers are continuing NF since long in some regions in different forms with satisfaction. Intuitively it echoes the possibility of regeneration of nutrients required for plant growth under NF through activation of different micro-organisms and addition of biomass in the soil. However, to prove this hypothesis and theory of change, there is a need for long-term field experiments by research institutions to understand the nutrients exchange through soil microorganisms in the soil system under different agro-climatic conditions, soil systems and cropping systems.

COMPARISON AMONG 3 FARMING PRACTICES

Specific inputs used | **Merits** / **Demerits**

Organic Farming

Specific inputs used
- Farm Yard Manure (FYM)
- Vermicomposting
- Bio fertilisers
- *Panchagavya*
- HYV/ Hybrid seeds
- Biological pest and diseases management

Merits
- Chemical free
- Eco friendly
- Assured market for contract farmers
- Premium price

Demerits
- Huge quantity of FYM
- Yield reduction during conversion period
- Stringent procedure
- Expensive for consumers

Natural Farming

Specific inputs used
- Indigenous cow centric
- *Jeevamritha* & FYM
- *Ghanajeevamritha*
- *Beejamritha*
- Mulching
- Inter- / mixed/ poly-crops
- Local cultivars seeds
- Home made materials (Kasayams) for pests & diseases control - *Agneyastra*, *Neemastra*, etc.

Merits
- Regular & better farm income from intercrop
- Lower production cost
- Less use of FYM/Inputs
- Improved family health- non-use of pesticides & food diversity
- Improved soil health
- Chemical free produce

Demerits
- Need of indigenous cow dung & urine
- Possibility of lower yield
- Cumbersome practices
- More farm engagement
- No established market/ certification

Chemical Farming

Specific inputs used
- Synthetic fertilizers
- Farm Yard Manure
- Chemical pesticides, herbicides
- HYV/Hybrid seeds
- Heavy Irrigation
- Intensive tillage
- Farm mechanizatior
- Mono-cropping systems

Merits
- High yield potential
- Convenience in farming
- Less price for customers
- Easy input availability
- Market well-established

Demerits
- Rising cost of production
- Health hazard for farmers & consumers both
- Unsustainable system
- Loss of biodiversity
- Pests resurgence

Natural Farming products may attract premium price & be placed between Conventional & Organic

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List of Abbreviations

A.P.	: Andhra Pradesh
APMC	: Agriculture Produce Marketing Committee
ASSOCHAM	: Associated Chamber of Commerce and Industry of India
ATIC	: Agriculture Technology Information System
B:C	: Benefit – Cost Ratio
CAGR	: Compound Annual Growth Rate
CMSA	: Community Managed Sustainable Agriculture
COP	: Conference of Parties
CRIDA	: Central Research Institute for Dryland Agriculture
CRZBNF	: Climate Resilient Zero Budget Natural Farming
CSKHPV	: *Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya*
FAO	: Food and Agriculture Organization
FPO	: Farmer Producer Organization
FYM	: Farm Yard Manure
GHG	: Green House Gas
GR	: Green Revolution
HYV	: High Yielding Varieties
ICAR	: Indian Council of Agricultural Research
ICRP	: Inter-Cluster Resource Person
K	: Potassium
KAR	: Karnataka
KRRS	: *Karnataka Rajya Raitha Sangha*
KVK	: Krishi Vignan Kendra
LVC	: *La Via Campesina*
MAH	: Maharashtra
NAAS	: National Academy of Agricultural Sciences
NBSS&LUP	: National Bureau of Soil Survey and Land Use Planning
NF	: Natural Farming
NGO	: Non-Governmental Organization
N	: Nitrogen
Non-NF	: Non-Natural Farming

NPK	: Nitrogen Phosphorus Potassium
NPM	: Non-Pesticidal Management
P	: Phosphorus
PGS	: Participatory Guarantee system
pH	: Potential of Hydrogen
PJTSAU	: Professor Jaya Shankar Telangana Agricultural University
RySS	: *Rythu Sadhikara Samstha*
S	: Sulphur
SOC	: Soil Organic Carbon
UN	: United Nation
ZBNF	: Zero Budget Natural Farming
ZBSF	: Zero Budget Spiritual Farming

1. Introduction

Microbes provide crucial ecosystem services …. The microbiota … in the soils in which these grow provide nitrogen, phosphorus and other essential nutrients. Microbes in the oceans produce 50% of the oxygen we breathe, and … remove roughly the same proportion of carbon dioxide from the atmosphere. They also remove up to 90% of the methane from the world's oceans.

Nicole et al (2015), *Nature* 526, 631–634.

Beneath the imprint of one's foot, extending down into the soil, are 300 miles of mycorrhizal fungal hyphae. In healthy soil, these fungi together with the full coteries of soil microbes help in regeneration, resilience and revitalization of soil system making all needed nutrients available to the plants through fixation, decomposition, solubilization and mineralization.

Michael Phillips (2017)

1.1 Setting the context

According to FAO, by 2050 the world needs to increase overall food production by 70 percent to keep up with the growing global population and the changes in consumption driven by expanding the middle class. At the same time, India is expected to be the most populous country in the world by 2030, with 1.51 billion people. Under such conditions, ensuring food security for the populace would be one of the biggest concerns for the country. Therefore, adopting of any farming practices or production technologies at large scale which are not scientifically proven and/or might have a negative effect on crop yield may pose serious concerns on the national goal of ensuring food and nutritional security. 'Green Revolution' technology (intensive use of HYV seeds, chemical fertilizer and irrigation) adopted in the mid-1960s helped in overcoming the food shortage in the country. However, intensification of agriculture had led to considerable adverse environmental impacts, soil degradation, eutrophication of land and water bodies, greenhouse gas (GHG) emissions and biodiversity losses (Evenson and Gollin, 2003; Canfield et al., 2010; Smith et al., 2013; IAASTD, 2009; Pingali, 2012). Contrastingly, Natural Farming (NF) is a unique chemical-free farming method that is considered to be an agroecology-based diversified farming system, which integrates crops, trees and livestock, allowing functional biodiversity (LVC, 2010; Rosset and Martinez-Torres, 2012). Zero Budget Natural Farming (ZBNF[1]) was originally promoted

[1] Though the proponent claims it to be 'Zero Budget Natural Farming' assuming no purchase of any input from market, we believe that every resource including home available human and/or

by an agriculturist Sh. Subhash Palekar in the mid-1990s, who have been awarded one of the highest civilian awards of India, Padma Shri in 2016 for promoting this alternative farming practices (Khadse *et. al.,* 2017; Mishra, 2018; Niyogi, 2018; Economic Survey, 2019). It has resulted in widespread adoption at varying levels in many states, especially, Andhra Pradesh, Karnataka, Maharashtra, Himachal Pradesh. It is considered to drastically cut down production costs by replacing the chemical fertilizers and pesticides with home-grown products like *Jeevamritha*, *Beejamritha*, *Neemastra*, etc, and adopting intercropping and mulching (Palekar, 2005; 2006). According to him, the method requires only one indigenous cow for 30 acres of land. It is also contemplated to promote soil health, improves soil organic carbon even without the need of adding a huge quantity of FYM (farmyard manure) as in the case of organic farming and thus help in attaining sustainable agriculture with the reduced carbon footprint. The Economic Survey (2019) emphasized the importance of Zero Budget Natural Farming (ZBNF) as one of the alternative farming practices for improving the farmers' income, in the backdrop of declining fertilizer response and farm income.

Biological sciences (e.g. microbiology, ecology, soil science) with their increasingly symbiotic (Gilbert et al., 2012) and "probiotic" (Lorimer, 2017) understandings of soil and plant life are also an inspiration for the ecological renewal of agriculture. Wallenstein (2017) argues that to restore soils, we need to feed the soil microbes. It can be done by adding organic material back to soil, minimizing tillage and stopping the use of synthetic fertilizer and chemicals. Initially, a Japanese farmer, Masanobu Fukuoka proposed natural farming, which is based on the philosophy of working with natural cycles and processes of the natural world (Fukuoka, 1987). It is contemplated as a solution to end reliance on purchased inputs, improved family health & nutrition, stable crop yield, consequently reduced indebtedness and suicides among Indian farmers.

1.2 Assents and criticisms of Natural Farming

In India, more than 85 percent of total 146.5 million farmers are smallholders and more than 100 million farmers (68.5% of total) are operating on an average 0.38 hectare (ha) land (MoA&FW, 2019. Hazell and Rahman (2014) reiterated that the majority of the poor and hungry people in the world live on small farms and struggle to subsist on too little land with low input-low yield technologies. Under such a scenario, the use of modern technology and innovation in Indian agriculture is being considered the only way out. Further, a section of scientific community and critics vehemently oppose this alternative practice condemning it is not based on scientific evidences, promoting certain beliefs system, particularly indigenous cows, a backward-looking and chauvinistic idiom (Shotwell, 2016; Saldanha, 2018; EPW, 2019). The National Academy of Agricultural

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material resources have opportunity cost. Therefore, we considered the practice as 'Natural Farming'. However, the terms ZBNF and NF have been used interchangeably in the report.

Sciences (NAAS) in India conducted a one-day brainstorming session at Delhi and reached a consensus that the government should not invest capital and human resources towards promoting ZBNF. It has also criticized ZBNF calling it an "unproven" technology that will not bring tangible gain to either farmers or consumers (Damodaran and Biswas, 2019). On the other hand, the Indian Council of Agricultural Research (ICAR) has appointed a committee under the Chairmanship of Prof. V. Praveen Rao, Vice-Chancellor, PJTSAU, Hyderabad to examine the ZBNF's viability. The committee is conducting experiments at five different locations in India.

Contrary to it, the protagonists of ZBNF believe that conventional agriculture or chemical farming contributes to land degradation by adding chemicals in soil and food systems, while agro-ecological system restores soil fertility. After having an exhaustive study of the movement, Munster (2018) believes that the prevalent ambivalence makes Natural Farming a valuable case for the political ecology of agriculture. Nevertheless, the Finance Minister, Govt. of India has stressed upon the ZBNF practices and appealed the farmers to replicate this innovative model that can help in doubling farmers' income. Furthermore, addressing the 14th Conference of Parties (COP) to the UN Convention to Combat Desertification, the Prime Minister of India mentioned that ZBNF is the way for sustainable agriculture.

> The Economic Survey (2019) categorized alternative farming practices like Natural farming or ZBNF as one of the organic farming models. It also highlights that the main aim of ZBNF is the elimination of agro-chemical and to sustain agricultural production with eco-friendly processes in tune with nature. Through ZBNF, soil fertility & soil organic matter is restored, less water is required, and it promotes climate-friendly agriculture system.

Interestingly, the Government of Andhra Pradesh took the unique initiative to improve farmers' livelihood through CRZBNF (Climate Resilient ZBNF), which later was changed to Andhra Pradesh ZBNF (APZBNF) to fight climate change in drought-prone Rayalseema region (Ananthapur, Prakasam, Kadapa, Kurnool and Chittoor) in 2015. Initially, 50 villages across 13 districts of the state were selected for the pilot project, however, later it has been expanded to the entire state (Niyogi, 2018). Moreover, the state earlier adopted Community Managed Sustainable Agriculture (CMSA), under which the use of chemical pesticides was replaced with a combination of physical and biological measures-including bio-pesticides. It also intended to reduce the use of chemical fertilizers. The CMSA was adopted by over 3,00,000 farmers in Andhra Pradesh state covering 1.36 million acres of farmland (Kumar et al., 2009). The same functional structure of CMSA has been used to promote the ZBNF practices in the state later. As per APZBNF, as on 31/12/2019, ZBNF is being practiced by 5.80 lakh farmers in 3011 villages of Andhra Pradesh state, covering 2.60 lakh ha cultivated area (apzbnf.in).

There are several variants of Natural Farming, under which the farmers do local customization and adaptation according to their local conditions. But, the steppingstone for ZBNF or Natural Farming in India is the advocacy by its chief proponent Sh. Subhash Palekar, who in due course also raised several controversies. Initially, he named the practice as 'Zero Budget Natural Farming' (ZBNF), which has been later changed to 'Zero Budget Spiritual Farming' (ZBSF), and sometimes, it has been renamed as 'Subhas Palekar Natural Farming (SPNF)'. He conducts training programmes for the farmers at different locations in different parts of the country and suggests following:

- **Since nothing to be purchased from the market under ZBNF practices, the production cost becomes zero. Therefore, it is named as 'Zero Budget'.**
- **All the needed nutrients are available in the soil, but in unavailable form. These can be converted into available form by the micro-organisms, which are available in plenty in the indigenous cow dung and uncultivated soil.**
- **Green Revolution technologies like chemical fertilizers and pesticides have destroyed these micro-organisms in the soil system.**
- **One gram of cow dung contains about 300 to 500 crore beneficial microbes, thus *Jeevamritha* acts as culture.**
- **Only dung of local cow is effective. One can mix half cow dung and half the dung of bullock or buffalo, but not of Jersey or Holstein at any cost.**
- **For one-acre land, only 10 kg/month of cow dung is sufficient. Therefore, a farmer can cultivate 30 acres of land with only one indigenous cow.**
- **The micro-organisms available in cow dung decompose the dried biomass (mulch) on the soil and make the nutrients available to the plants. It also increases earthworm population in the field.**
- **Thus, *Jeevamritha* is perfect and complete solution for crop cultivation. There is no need to add FYM in bulk quantity.**
- **Organic farming is not suitable for poor Indian farmers, as it requires huge quantity of FYM, making their agriculture unremunerative. Besides, the worms *Eisenia foetida* used in vermi-composting convert considerable amounts of heavy metals into bio-available form, and the roots absorb these poisonous heavy metals which ultimately enter into the human food chain.**

Source: http://www.palekarzerobudgetspiritualfarming.org/zbnf.aspx

Globally, soils contain more carbon than plants and the atmosphere combined. Losing carbon-rich organic matter from soils releases carbon dioxide, a greenhouse gas, which can accelerate climate warming. But by regenerating soils, we can sequester more carbon underground and slow climate warming. In addition to protecting soil, cover crops take carbon out of the atmosphere as they grow and funnel it into the soil. Unlike cash crops that are harvested and removed from the soil, cover crops are left to decompose and contribute to soil formation. While plants are the source of carbon for soils, microbes control its fate by using it as food, thus ensuring that at least some of it will remain in the soil (Wallenstein, 2017). Thus, it is believed that ZBNF or Natural Farming is based on the above hypothesis. With different interventions under it- adding microbes, adding cover crop, minimum tillage, multi-cropping, etc. it helps in soil regeneration and ultimately would lead to sustainable agricultural growth.

1.3 Organic Farming *vs* Natural Farming

Despite rapidly growing market of organic food and beverages, organic farming has a history of being contentious and is considered as an inefficient approach to food production. Although the demand for organic food products is on constant rise worldwide. Despite the growing trend in demand for organic products, consumers of organic products recently witnessed periodic shortages of organic products, primarily because supply of organic foods failed to catch up with the rapidly increasing demand (Dimitri and Oberholtzer, 2009). Currently, India is home to 30 percent of the total organic producers in the world, though it accounts for just 2.59 percent (1.6 million hectares) of the total organic cultivation area of 57.8 million hectares in the world, according to the World of Organic Agriculture 2018 report. At the same time, organic products are usually 3-4 times more expensive due to higher labour cost, certification costs, handling costs and comparatively lower yields. If a farmer wishes to convert to organic farming, s/he must go through a three-year transition period during which they are required to practice organic farming but not allowed to sell products as organic. With the typically lower yields during this transition period, the conversion process poses a significant financial risk to the farmers.

On the other hand, if Natural Farming (NF) gets recognition as chemical-free production practices, farmers can sell their produce as 'Green Product' from the first year itself at a little premium price. It would help in compensating the yield loss if any during initial years. According to a study by TechSci Research, the global organic food market stood at $110.25 billion in 2016 and is projected to grow at a CAGR of 16.15 percent, to reach $ 262.85 billion by 2022. In India, its market has been growing at a CAGR of 25 percent and is expected to touch ₹10,000-₹12,000 crores by 2020 from the current market size of ₹4,000 crores, according to a report produced jointly by ASSOCHAM and Ernst & Young. India exported organic products worth ₹ 5,151 crores in 2018-19, about 50% higher than the previous year (Annexure III). Currently, 1.78 million hectares of the cultivated area is under organic farming in India. However, very high price of organic food products as compared to conventional food makes it inaccessible to middle-class population. The high price is attributed to high input cost, labour cost, separate handling charges, cost of certification as well as low yield during conversion period of 3 years during which farmers have to do organic farming but can't sell the produce as organic. The high price of organic products is also because of the cost associated with the logistic cost involved in the procurement of organic products from certified organic farms and the distribution within the city increases the cost of the products.

> Organically grown products have higher antioxidant, lower cadmium concentrations and lower incidence of pesticide residues. High concentrations of a range of antioxidants such as polyphenolics found in organic crop-based foods are linked to a reduced risk of chronic diseases, including CVD and neurodegenerative diseases and certain cancers (Baranski et al., 2014).

However, one school of thought considers that the carrying capacity of organic agriculture is 3–4 billion only (Connor, 2008), well below the present world population (6.2 billion) and that projected for 2050 (9 billion). Contrary to it, Badgley et al. (2007) showed that organic agriculture cannot only increase crop productivity in developing countries but could feed the entire world also. Barbieri et al (2019) estimated the possible crop substitution due to organic farming. The study indicated a decrease of (−) 31% harvested area, with primary cereals (wheat, rice and maize) compensated by an increase in the harvested areas with temporary fodders (+63%), secondary cereals (+27%) and pulses (+26%) compared with the conventional situation. These changes paired with organic-to-conventional yield gaps may lead to a −27% gap in energy production from croplands compared with current production. Furthermore, while assessing the efficiency of changes in land use for climate change, Searchinger *et al* (2018) argued that organically farmed food has a bigger climate impact than conventionally farmed food, due to the greater areas of land requirement. This is due to much lower crop yield harvested, primarily because fertilizers are not used. To produce the same amount of organic food, we need a much bigger area of land, which indirectly leads to higher carbon emissions. Though, from consumers' point of view, organic food seems to be more climate-friendly.

Contrary to these arguments for organic farming, Sh. Subhash Palekar contests that organic farming as an alternative to conventional farming is doing more harm to Indian agriculture. Firstly, organic farming requires huge quantity of organic matter, viz. FYM, which may not be available for most of the farmers in India. Therefore, they have to purchase cow dung in huge quantities, adding costs and making agriculture economically unviable. This is the reason that organic produce has become an elite product and only rich people can purchase it at a very high price. Secondly, several government agencies and NGOs are propagating vermicompost for organic farming, in which they use different variety of earthworm named as '*Eisenia foetida*' (Fig. 1a), which is commonly known as redworm. Though it belongs to earthworm family, it is a surface feeder and lives only on the organic matter available on surface soil, and decomposes dried vegetation, compost or manure. They do not burrow into the soil like local earthworm (Fig. 1b) and thus cannot convert the deep soil into casting, which is the richest stock of minerals necessary for plant growth. Therefore, for Indian conditions and Indian smallholder farmers, Natural Farming practice is more useful than that of organic farming or conventional input-intensive farming.

Fig 1.0 Local and *Eisenia fetida* species of earthworm

1.4 Objectives of the study

Keeping in view the above-mentioned contemporary issues of agrarian distress and the methods and practices suggested under Natural Farming, following research questions emerged:

- What are the components of Natural Farming (NF) mostly adopted by the farmers in study region?
- What crops are being cultivated by the farmers in different states/ regions using Natural farming and its effect on the crop yields?
- Whether application of *Jeevamritha* increases soil microbial activities to such extent that all the plant nutrients become available to the crops?
- What are the effects of natural farming on production ecosystem, crop yield and farmers' livelihood?

Specific objectives:

1. **To understand perception of the farmers adopting and not adopting the Natural Farming in selected study region(s);**
2. **To analyze the properties of the soil and the plant parts from the adopted farmers' fields;**
3. **To estimate the cost of cultivation and income gain by the adoption of NF practices;**
4. **To examine the sustainability and scalability of NF for the study regions.**

1.5 Limitations of the study

The study is based on field survey of farmers therefore, it has usual limitation of survey-based study, which are as follows:

- **Due to unavailability of any official list of farmers practicing Natural Farming (NF), the survey mainly depended on self-declaration by the farmers and/or neighbouring farmers about NF-adoption.**
- **The study also depended heavily on the information shared by the sample farmers on recall basis. It is believed that the farmers have given their information truthfully and as per their best knowledge, assuming no incentive by distorting the facts for randomly selected farmers.**
- **The soil and plant samples have been collected from the farmers' fields, for which we don't have any baseline information. Further, the team had no control over different practices undertaken by the two sets of farmers, which might influence the results of soil and plants samples from NF and non-NF field.**
- **The results presented in the report mainly reflect the trend in the study area. It may not be replicable in other locations with different agro-climatic conditions and different cropping patterns.**

2. Study Area, Data and Methodology

2.1 Study area and sampling methodology

Natural Farming (or ZBNF) involves the application of *Jeevamritha, Beejamritha,* mixed cropping system, home-made preparations for plant protection and seed/planting materials, and mulching. Thus, it envisages complete freedom from chemicals from farming. Therefore, for the identification of Natural Farming (NF) adopter farmers, only those farmers were selected for the study who is using at least *Jeevamritha* and not using any chemicals (fertilizers/pesticides/growth promoters). Both the conditions together were considered essential for terming as NF-adopter farmers. These farmers were selected using snowball sampling in the sample districts, as there was no authentic database available about the adopter farmers. For this, districts were identified with the help of State Agricultural Universities located in the respective states.

The study is based on extensive field survey and interaction with adopted and non-adopted farmers in Karnataka, Andhra Pradesh (A.P.) and Maharashtra during February- May 2019. In all the states, 2-3 districts having higher proportion of farmers adopting Natural Farming were selected (Table 2.1 & Fig. 2.1). To have comparative assessment, non-NF farmers were also selected from the same villages. In all, 120 NF-adopted and 60 non-adopted farmers in Andhra Pradesh and Maharashtra each were surveyed using a pre-tested and structured survey schedule. In case of Karnataka, during field survey it was very difficult to get NF-adopted farmers. Most of the villages were having only one or two NF adopted farmers. And because of this, survey was done extensively covering 29 villages to find NF adopted farmers. Even though only 55 NF adopted farmers were identified and interviewed. It can be presumed that almost all the NF farmers have been surveyed in the selected districts of Karnataka who qualified the criteria of NF-adopters.

Table 2.1. Distribution of sample farmers in the study

State	District	No. of villages covered	NF-adopted farmers	Non-adopted farmers	Total sample farmers
Andhra Pradesh	Vishakhapatnam	5	60	30	90
	Vizianagaram	5	60	30	90
Karnataka	Mandya	10	32	24	56
	Ramanagara	8	7	10	17
	Tumakuru	11	16	16	32
Maharashtra	Parbhani	6	60	30	90
	Hingoli	7	60	30	90
	Total sample size	**52**	**295**	**170**	**465**

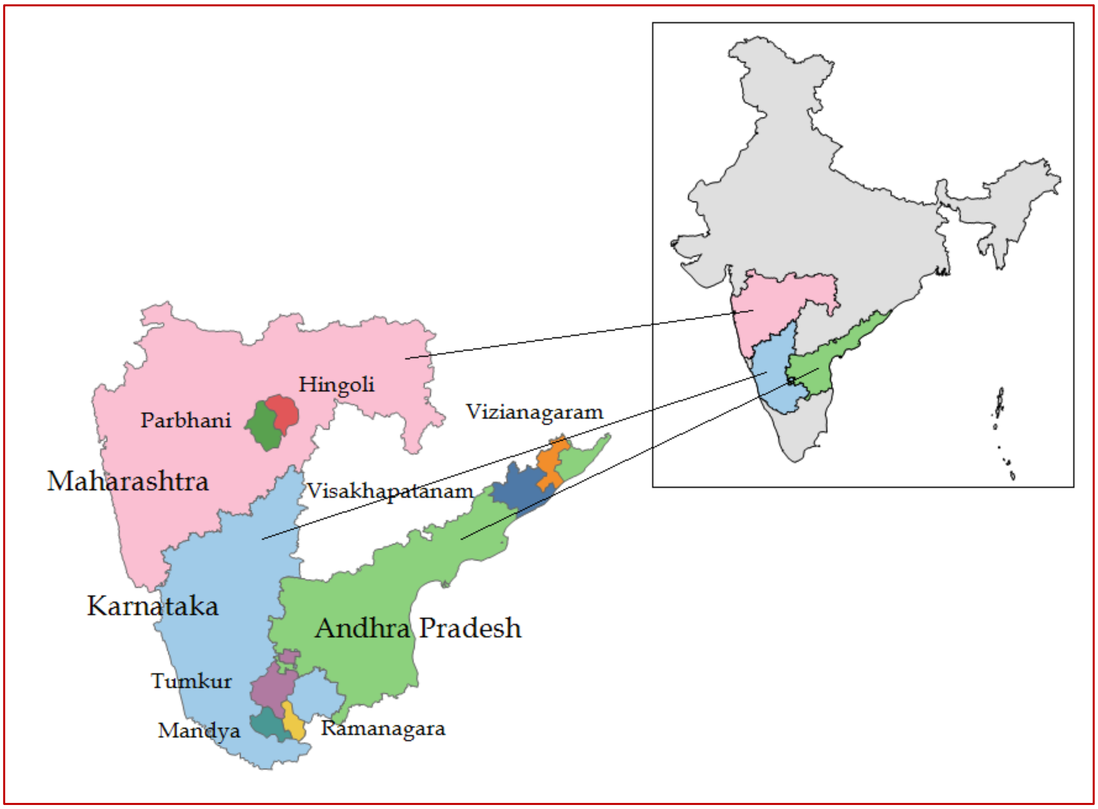


Fig. 2.1 States and sample districts for the study

2.2 Description of the study area

Symbol	Andhra Pradesh		Karnataka		Maharashtra	
	Vishakha-patnam	Vizia-nagaram	Mandya	Tumakuru	Hingoli	Parbhani
	3,265	1,534	1,486	2,727	714	851
	1,116.1	635.9	498.2	1059.7	466.1	631.1
	304	311.6	225	582.6	382	519
	100.5	147	126.2	117.8	89	132
	Canal (≈40%)	Tanks (>50%)	Canal (≈75%)	Bore well (> 80%)	Canal (≈50%)	Canal (>80%)
	Red clay/ sandy loam, coastal sandy, clay loam	Red clay, loamy, sandy loam soil	Red gravel, red sandy loam, red sandy soil	Black, red, sandy and sandy loam soil	Deep black, shallow soil	Deep black, shallow soil
	Paddy, sugarcane, groundnut, finger millet, mango, vegetables				Soybean, cotton, sorghum, pigeon pea, green gram, black gram, chickpea, vegetables	
	cashew, coconut	green gram, black gram, sesamum, maize, cashew	horse gram, cowpea, maize, banana, coconut	maize, Jowar, pigeon pea, banana, coconut, arecanut	wheat, safflower, turmeric,	sugarcane, mango
	Ongole, Deoni, Hallikar, Panganur	Ongole	Hallikar	Amrithamal Hallikar	Gir, Khilar, Deoni, Dangi, Red Kandhari	
	355.5	169.6	153	303	260	350
	≈1,200	≈1,100	≈718	582.6	≈945	≈960

Symbols:

No. of villages; Geographical area ('000 ha); Net sown area ('000 ha)

Net irrigated area ('000 ha); Major Irrigation sources; Major soil types

Major crops grown; Major indigenous cattle breeds

Indigenous cattle population in ('000) (2012); Annual rainfall (mm)

3. Indian Soils and Natural Farming Practices

Soil is a fundamental and essential natural resource for existence of all living organisms. Soil health or quality is defined as the capacity of soil to function as a vital living ecosystem that sustains plants and animals. Intensive crop cultivation using broadly using imbalanced fertilizer, high nutrient mining through monoculture, decline in organic matter status, deficiencies of secondary and micronutrients, etc. have deteriorated the soil health across the region in India resulting into declining crop productivity growth. There are 6 major soil types in India- Alluvial soil, Red soil, Black soil, Laterite soil, Arid soil and Forest & mountain soil (Fig. 3.1). Each soil type has its own characteristics in terms of physical and chemical properties, like Alluvial soil is highly fertile, with high phosphorus and potash content. Laterite soil is acidic in nature, while Black soil is rich in potash and magnesium, but poor in phosphorus. Red soil has high iron and potash content but lacks phosphate.

3.1 Nutrient deficiency in Indian soils

Overall, about 59 and 36 percent of Indian soils are low and medium in available N, respectively. Similarly, soils of about 49 and 45 percent area are low and medium in available P, respectively; while soils of around 9 and 39 percent area are low and medium in available K, respectively (Chaudhari *et al.*, 2015). Among various soil characteristics that affect the availability and uptake of micronutrients, soil pH and organic carbon content are the two most important factors.

The availability of most micronutrients is higher in acidic soils as compared to alkaline soils (Fig. 3.2). Soil pH between 6 and 7 shows the highest availability of micronutrients (pwc, 2019). Since 71% of Indian soils are moderately alkaline, soil micronutrients tend to be deficient in them.

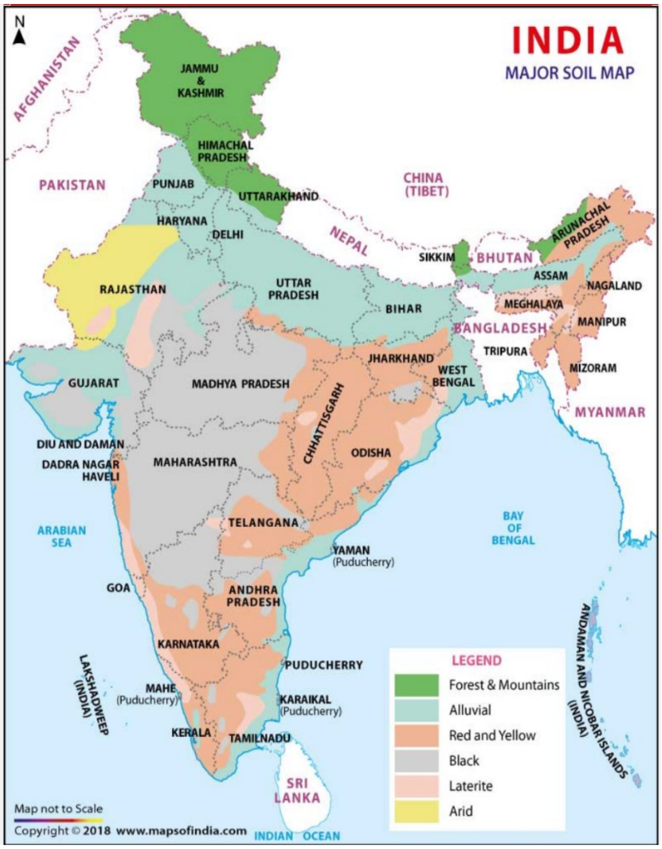


Fig. 3.1 Major soil types in India

Source: https://www.mapsofindia.com

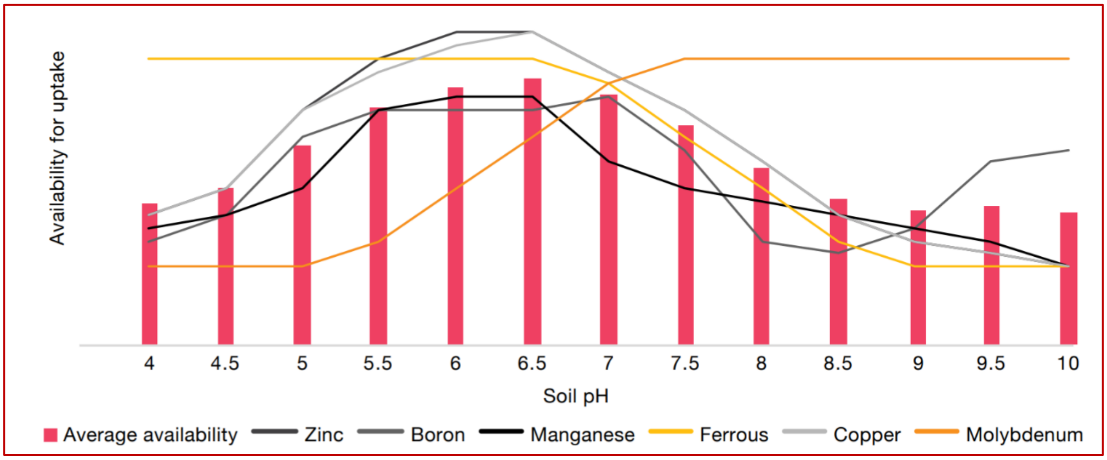


Fig. 3.2 Effect of pH on availability of micro-nutrients

Source: pwc (2019)

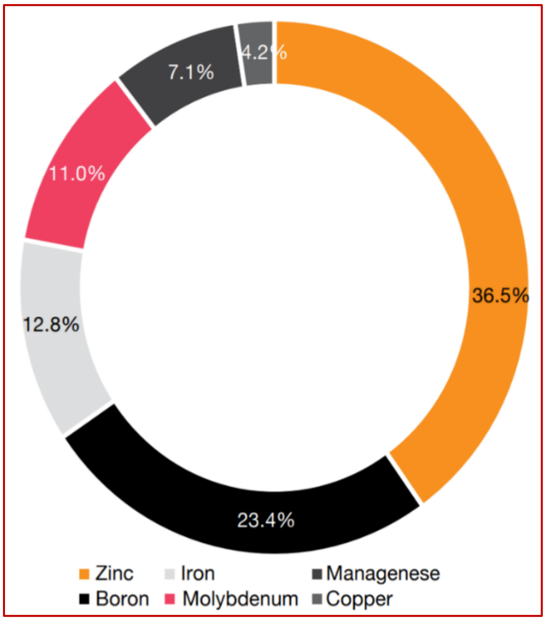


Fig. 3.3 Micro-nutrient deficiency in Indian soils

Source: Shukla et al (2018)

Analysis of more than two lakhs soil samples during 2011-2017 revealed huge variation in different types of micronutrients deficiency in India soils (Fig. 3.3 and Annexure I). On an average, 36.5, 23.4, 12.8, 11.0, 7.1 and 4.2% soils are deficient in zinc, boron, iron, molybdenum, manganese, and copper, respectively, across the country (Shukla et al., 2018). Our soils are very low in organic matter content and thus have poor soil fertility. Organic carbon is an index of good soil health and application of organic manures helps in maintaining high organic carbon content of the soil.

Soil organic carbon (SOC) is the key constituent which dictates soil physical condition, chemical properties including nutrient status and biological health of a soil (Bhattacharyya et al., 2000). Management practices that reduce organic matter in soils, or bypass biologically-mediated nutrient cycling also tend to reduce the size and complexity of soil communities. Soil organisms, both animals (fauna/micro-fauna) and

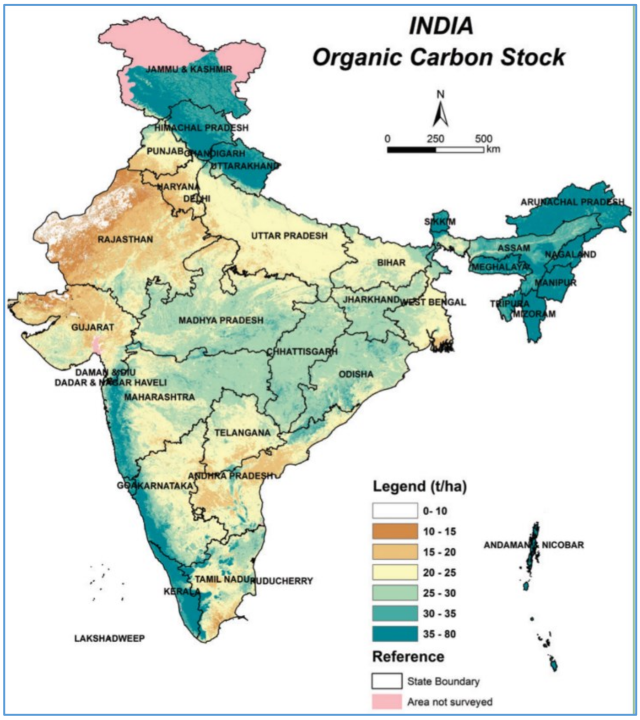


Fig. 3.4 SOC stock map of India
Source: ICAR-NBSSLUP (2017-18)

plants (flora/micro-flora), are important for maintaining the overall soil quality, fertility and stability of soil (Velayutham et al., 2000). Soil organic matter helps soils hold onto water and nutrients and supports soil microbes that recycle nutrients. They are intimately associated with biological and biochemical transformations occurring in soil (NAAS, 2018). According to the estimates by ICAR-NBSS&LUP (2017-18), there is a huge variation in SOC stock across states. The SOC stock of Indian soils is 10 to 12% of the tropical regions and about 3% of the total carbon mass of the world (Fig. 3.4).

3.2 Role of soil micro-organisms

For sustainable farming, healthy soil is the most important factor. Soil microbiologists believe that healthy soil means living soil, which involves trillions upon trillions of living microorganisms consuming first organic matter, then each other, and releasing nutrients in the process (Fig. 3.5). They have also recognized some 150 species of arbuscular mycorrhizal fungi (MF) that colonize the root systems of plants. Plants offer photosynthetic sugars to MF, which in turn assist the plant by facilitating the uptake of mineral nutrients and water. In healthy soil, mycorrhizal fungi grow immensely which works like sponge (Fig 3.6). It helps in improving soil aggregate stability, build soil carbon, improve water use efficiency, increase the efficiency of nitrogen, phosphorus and sulphur. To increase the mycorrhizal fungi, it needs to reduce/eliminate chemical use, reduce/eliminate tillage, reduce/eliminate synthetic fertilizers and living plant cover as long as possible. Cover crop also reduces soil temperature, which improves soil moisture condition and in turn helps in soil bacterial growth. Thus, it also helps in building a **soil carbon sponge**, which absorbs water and make available to the plants (Phillips, 2017). Further, Jehne (2019) states that 95% of the bio-fertility of soils is about these microbial processes, not the actual nutrient content in the soil or how much we put on as fertilizer. The application of chemical fertilizers, biocides, tilling of lands, etc. is detrimental to these soil micro-organisms, and consequently, roots of the plants act simply as straw sucking mainly those nutrients, which has been supplied externally in the forms of chemical fertilizers. While through biological processes, all kinds of nutrients are made available to the plants through the decomposition of root biomass of previous crops or mulches.

The study has shown that crop residues are good sources of plant nutrients and can increase yield and water use efficiency while decreasing weed pressure. Long-term studies of residue recycling have indicated improvements in the physical, chemical and biological health of soil (Singh and Sidhu, 2014). For example, about 40% of the N, 30-35% of the P, 80-85% of the K, and 40-50% of the S absorbed by rice remain in the vegetative parts at maturity (Dobermann and Fairhurst, 2000; Dobermann and Witt, 2000), similarly, about 25-30% of N and P, 35-40% of S, and 70-75% of K uptake are retained in the wheat residue.

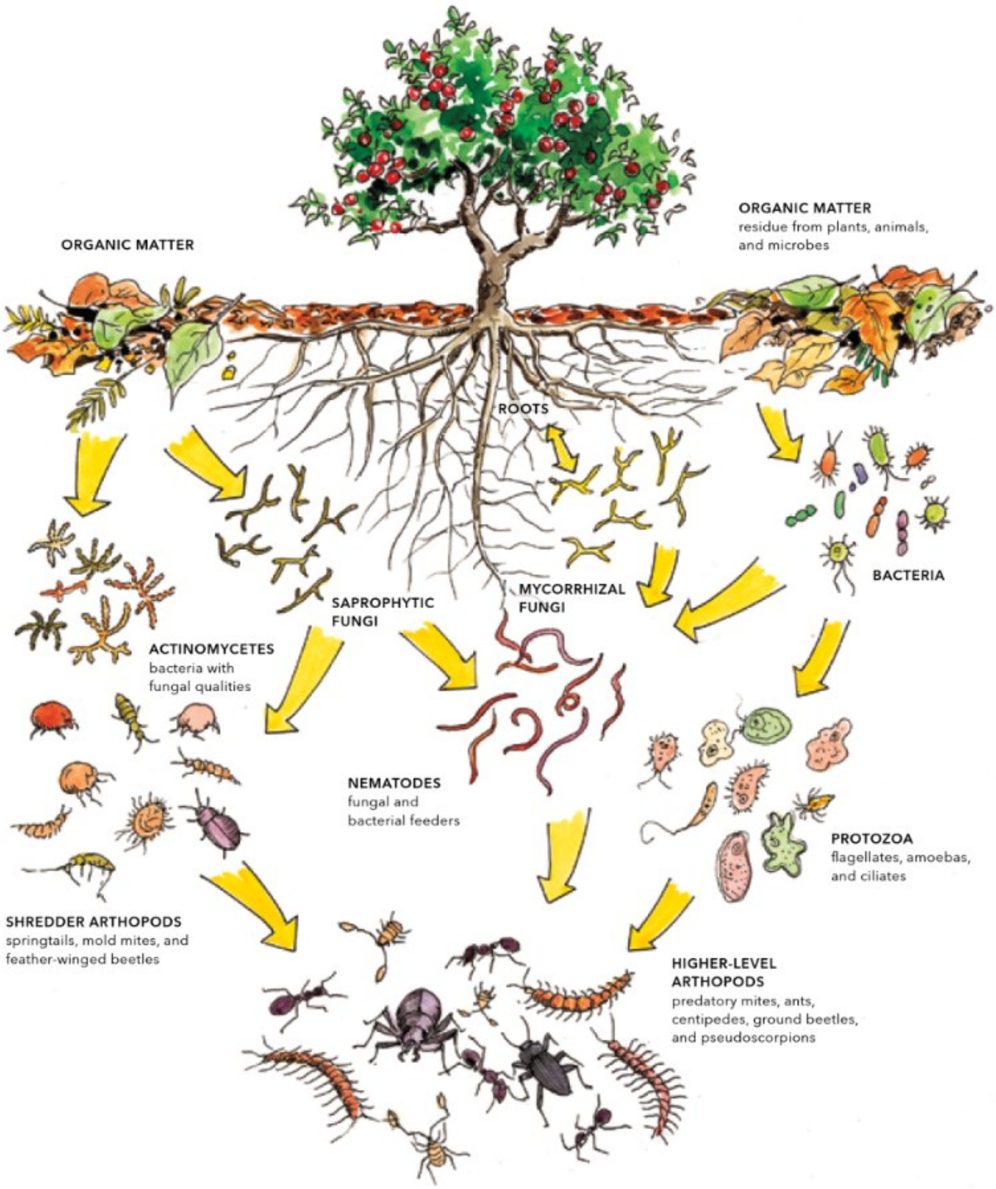


Fig. 3.5. Interdependent and interconnected network of microorganisms with plants (Source: Phillips, 2017)

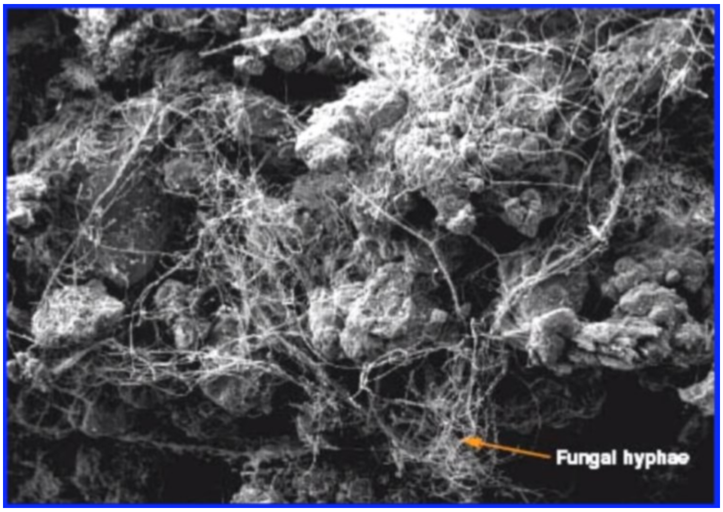


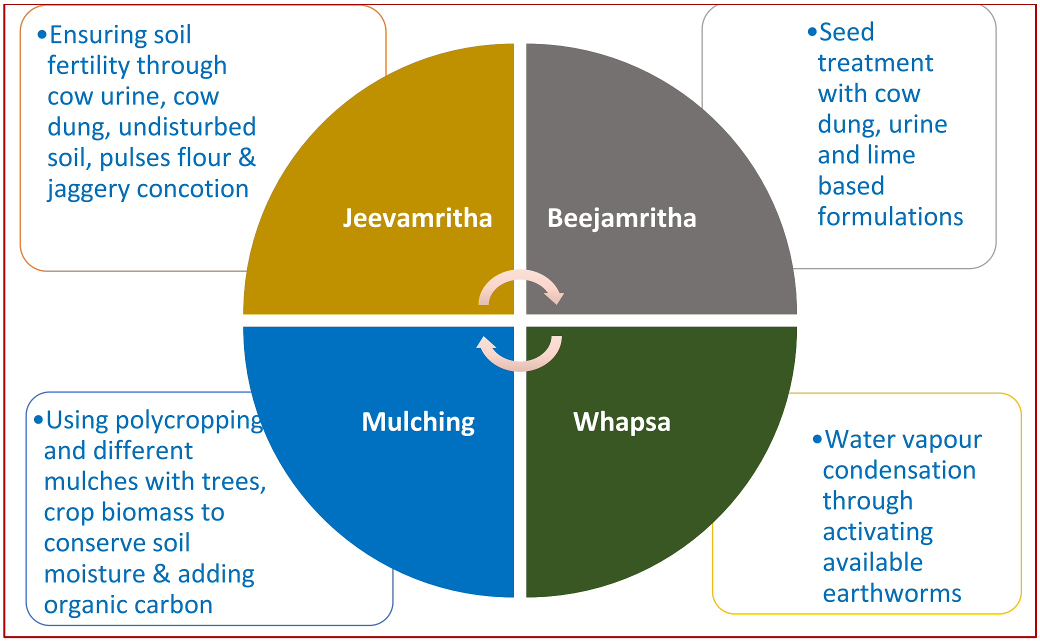
Fig. 3.6. Web of mycorrhizal fungi in healthy soil (Source: Fulton, 2011)

New research suggests that microbes perform critical function in soil food webs, such as decomposing organic materials, cycling nutrients and improving soil structure. These microbes interact closely with each other, forming complex networks. They work in teams to complete biochemical processes. Adding efficient microbes to soils can enhance the percentage of plant carbon that is transformed into soil, thus soil regeneration can be accelerated far beyond typical rates seen in nature (Wallenstein, 2017).

3.3 Subhash Palekar's Approach of ZBNF

In the study, both the terms Natural Farming and Zero Budget Natural Farming (ZBNF) have been used interchangeably and the practices propagated by Sh. Subhash Palekar has been considered as a reference point. ZBNF aims to improve soil health by improving the soil biological activity by adding microbe inoculants and organic matter. The practices of Natural Farming include the addition of microbial cultures to enhance decomposition and nutrient recycling; use of local seeds; integration of crops, trees and livestock (mainly cows of native breeds); effective spacing of crops, contouring and bunds to conserve water; intensive mulching; extensive intercropping and crop rotations. Moreover, mulching has huge positive effect on SOC content due to enhanced soil and water conservation, lower average and maximum soil temperatures under mulch than in unmulched soil surface, return of biomass to the soil, increase in soil biodiversity, and strengthening of the nutrient cycling mechanisms (Lal and Kimble, 2000).

According to Sh. Subhash Palekar, the ZBNF/NF has following 4 essential components:



1. ***Jeevamritha/*** *Jeevamrutha* is a fermented microbial culture. It provides nutrients, but most importantly, acts as a catalytic agent that promotes the activity of microorganisms in the soil, and also increases the population of native earthworms.
   - *Preparation of Jeevamritha:*
     - Put 200 litres of water in a barrel
     - Add 10 Kg fresh local cow dung
     - Add 5 to 10 liters aged cow urine
     - Add 2 Kg of Jaggery (a local type of brown sugar)
     - Add 2 Kg of pulses flour and
     - Add a handful of soil from the bund of the farm.

   Stir the solution well and let it ferment for 48 hours in the shade. *Jeevamritha* is ready for application. The 200 litres of *Jeevamritha* is sufficient for one acre of land. During the 48-hour fermentation process, the aerobic and anaerobic bacteria present in the cow dung and urine multiply as they eat up organic ingredients (like pulse flour and jaggery). A handful of undisturbed soil acts as inoculate of native species of microbes and organisms. *Jeevamritha* also helps to prevent fungal and bacterial plant diseases.

   - *Application of Jeevamritha:* It should be applied to the crops twice a month in the irrigation water or as a 10% foliar spray. The preparation is stored up to a maximum of 15 days and used in the field either through spray or mixing with irrigation water. For horticultural crops, *Jeevamritha* is applied to the individual plant. In Maharashtra, majority of the sample farmers are applying *Jeevamritha* through drip irrigation method.

Fig. 3.7 *Jeevamritha* being prepared by the paddy grower

Box 1. Microbial activity in soil and cow dung

Proponents of Natural Farming argue that the dung of indigenous cow and small quantity of undisturbed soil has huge number of diverse micro-organisms which help in increasing the bio-availability of nutrients to the plants. Soil is a complex ecosystem hosting bacteria, fungi, plants, and animals (Bonkowski et al., 2009; Muller et al., 2016). Soil microbes metabolize recalcitrant forms of soil-borne nutrients to liberate these elements for plant nutrition. In natural ecosystems, most nutrients such as N, P, and S are bound in organic molecules and are therefore minimally bioavailable for plants. To access these nutrients, plants are dependent on the growth of soil microbes such as bacteria and fungi, which possess the metabolic machinery to depolymerize and mineralize organic forms of N, P, and S (Jacoby et al., 2017).

Sawant et al. (2007) have isolated many different bacterial genera such as *Citrobacter koseri, Enterobacter aerogenes, Escherichia coli, Klebsiella oxytoca, Klebsiella pneumoniae, Kluyvera spp., Morgarella morganii, Pasteurella spp., Providencia alcaligenes, Providencia stuartii* and *Pseudomonas spp.* from cow dung. Gupta et al. (2016) found that many cow dung microorganisms have shown natural ability to increase soil fertility through phosphate solubilization. Lu et al. (2013) isolated 219 bacterial strains from cow dung, among which 59 isolates displayed nematicidal activity against >90% of the tested nematodes. Cow dung has antifungal substance that inhibits the growth of coprophilous fungi (Dhama et al. 2005).

2. ***Beejamritham*** is a treatment used for seeds, seedlings or any planting material. *Beejamritha* is effective in protecting young roots from fungus as well as from soil-borne and seed-borne diseases that commonly affect plants after the monsoon period.

    - *Preparation of beejamritha-* Mix local cow dung, considered to be natural fungicide, and cow urine (as anti-bacterial liquid), lime and soil. The dung is tied in a cloth and is kept in urine for about 12 hours. The dung is removed from cow urine, cow dung is squeezed and urine is added with about 50 grams of lime.

    - *Application as a seed treatment:* Add *beejamritha* to the seeds of any crop; coat them, mixing by hand; dry them well and use them for sowing. For leguminous seeds, just dip them quickly and let them dry.

3. ***Acchadana - Mulching***. Three types of mulching have been suggested under ZBNF:

    a. **Soil Mulch**: This protects topsoil during cultivation and does not destroy it by tilling. It promotes aeration and water retention in the soil. Therefore, deep ploughing should be avoided.

    b. **Straw Mulch:** Straw material usually refers to the dried biomass waste of previous crops. Any type of dry organic material will decompose and form humus through the activity of the soil biota which is activated by microbial cultures.

    c. **Live Mulch**: It is essential to develop multiple cropping patterns of monocotyledons and dicotyledons grown in the same field, to supply all essential elements to the soil and crops. Dicot group such as pulses are nitrogen-fixing plants. Monocots such as rice and wheat supply other elements like potash, phosphate and sulphur.

4. ***Whapasa- moisture:*** The advocates of ZBNF counter the over-reliance on irrigation in green revolution farming. Whapasa is the condition where there are both air molecules and water molecules present in the soil. Thus, irrigating only at noon, in alternate furrows, may fulfill the moisture requirement of the crops, a significant decline in the need for irrigation in ZBNF. However, rarely this practice is being followed by any farmer.

3.3 APZBNF implementation in Andhra Pradesh state

Government of Andhra Pradesh has set up a non-profit company called *Rythu Sadhikara Samstha* (RySS) in the year 2015 to implement in entire state the Andhra Pradesh Zero Budget Natural Farming (APZBNF), earlier known as Climate Resilient ZBNF (CRZBNF). It claims to have brought more than 5.8 lakh farmers across 3,067 villages under Natural farming (APZBNF, n.d.). It follows the same principles as suggested by Sh. Subhash Palekar, with few modifications or local customization depending on availability of inputs and other local conditions. The CRZBNF aims to cover 80% of the cropped area in the state. According to RySS, most of the farmers take 3 years to convert into 100% ZBNF farmers. It also focuses on the full village to convert the whole village into **Bio-village** in 5 years.

The modifications/variations in CRZBNF found during interaction with RySS officials as well as during field survey are as follows:

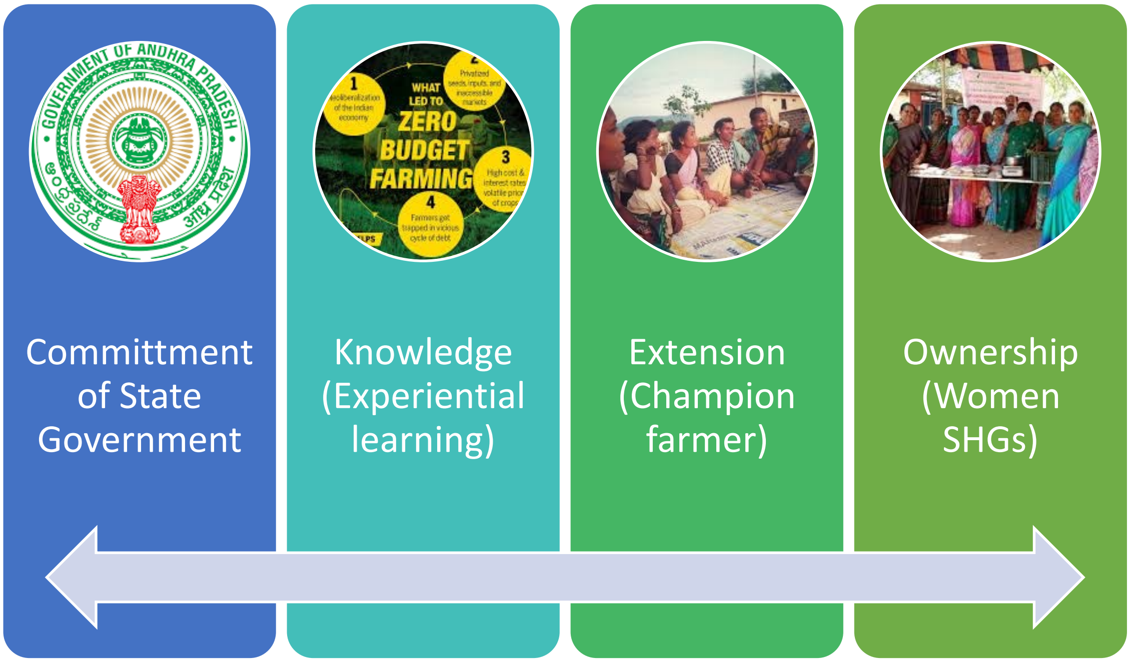
a) ***Ghanajeevamritha***, a solid form of *Jeevmaritha* is prepared by farmers in areas where water availability is scarce. The farmers prepare *Ghanajeevamritha* during the off-season and stored up to a maximum of six months to be used in next crop season. Cow dung and urine are mixed with pulse flour, jaggery made into ball like structures and dried under the shade. The dried product is stored in gunny bags and finely powdered before applying in the field. The farmers apply the *Ghanajeevmritha* by broadcasting method before sowing of the crop.

b) **Pre-monsoon dry sowing (PMDS)**: In the rainfed and unirrigated region, the beejamritha treated seeds are broadcasted in the field before the onset of monsoon. *Beejamritha* helps in combating unpredicted and less rain for Kharif crop and also protects seeds from being eaten by birds. The seeds germinate whenever first rain happens for which farmer need not wait. It helps in avoiding repeat sowing due to monsoon failure/delay.

c) **Poly-cropping:** 5-layer cropping in which different layers of crops comprising of trees, fruits, vegetables, pulses and cereals are grown. These have different levels of canopies and maturity period, thus are harvested at different point of time. Among these crops, some may act as border crop, other as trap crop or pulses, vegetables, cereals, etc. It thus helps in providing one or other produce to the farmer at regular interval.

d) ***Navadhanya:*** Mixing seeds of nine millets/crops and broadcasted as green manure before Kharif season. The grown-up plants act as manure for the Kharif crop by the farmers.

The model followed by RySS is based on the following pillars:



APZBNF is following unique extension model, under which emphasis is being given on farmer-to-farmer dissemination of knowledge. The RySS is working with agriculture department of the state. At field level, it is engaging agriculture graduates as Natural Farming Fellows (NFFs), one for 5 villages (2000 farmers), who are responsible for giving training to the farmers for ZBNF practices. These NFFs do multiple roles- farmers, trainers, researchers, and team leaders. Besides, the best practicing farmers are identified as 'Community Resource Persons' (CRPs). One CRP is selected per 50 to 100 farmers and one senior CRP is identified per Gram Panchayat for 400 farmers.

3.4 Pest control solutions

According to ZBNF-adopter farmers, when chemical fertilizers are applied to the crops, the vegetative growth of the crop is very good and lush green. This attracts the insects/ pests to the crops. While in case of *Jeevamritha*, the leaves colour is not that much green, and therefore, menace of pests is limited. However, when infestation occurs, the farmers prepare different types of formulations (*Kashayam*) made up of locally available plant materials to control the pests. Some of these are:

1. ***Neemastra*** is the most commonly used pest controlling solution which is prepared by the farmers. Cow dung, cow urine, neem leaves, and water are used for preparing the neemastra. The neem leaves are grinded into paste and added with water. The solution is directly applied to plants without any further dilution. For this, 5 kg of neem paste is added with around 2-3kg of dung, 10-20 litres of cow urine, handful of soil. The solution is fermented for about 48 hours. It was found that the farmers are making the solution ranging from 100-200 litres depending upon their usage and crops grown.

2. ***Brahmastra*** is prepared from five types of bitter leaves. Neem leaves are used along with the other bitter-tasting leaves, like custard apple, chillies, etc. Around 20-30 litres of cow urine is used and is boiled for about 2-3 hours. The solution is cooled for about 12 hours and is filtered using fine cloths. The solution is further diluted with about 15 litres of water for every 1 litre of Brahamastra. The farmers are using 10-20 litres of cow urine and 5kg of neem leaves in preparing Brahmastra.

3. ***Agniastra*** is prepared by adding 5 kg of neem paste with around 1 kg of tobacco leaves, 0.5 kg of chillies and 0.5 kilo of garlic paste. These are added in about 25-30 litres of cow urine and is cooled down for about 24 hours. The solution is then filtered and used. The solution is diluted before applying in the field for every half litre of Agniastra about 15 litres of water is added. Agniastra is considered to be effective against insects like Leaf Roller, Stem Borer, Fruit borer, Pod borer.

The pest controlling solutions were also made available to the farmers at NPM (Nutrients Pest management) shops in Andhra Pradesh. Apart from the above-mentioned solutions, there are other pest controlling solutions being used by the farmers. It is being used by the farmers mainly in the paddy crop.

4. ***Tutikada rasam*** is prepared from datura leaves and cow urine. The leaves are boiled in cow urine for 2-3 hours and is cooled then it is filtered using a cloth.

5. ***Dashparini Kashyam*** It is prepared from ten types of plant leaves. The leaves of Neem, *Agele marmelos*, Calotropis, *Senna auriculata*, Papaya, Custard apple, Gauva, *Vitex negundo*, castor, Pomegranate, Nerium, Ocimum, Aloe vera, Tobacco, Datura, *Lantana camara* and *Pongamia pinnata* are used in preparing the solution. Green chilli and garlic are also crushed and added and mixed with 20 litres of cow urine. It is kept up to 45 days for fermentation. The solution is filtered and sprayed after dilution. In about 8-10 litres of solution 100 litres of water is added for dilution.

Fig. 3.8 Sugarcane trashes used as mulch in the NF field in Karnataka

Fig. 3.9 *Azolla* used as mulch by paddy growers in Andhra Pradesh

4. Sample Farmers and their Choice of Crops

4.1 Demographic characteristics

The sample farmers in the study area comprised both young and mid-aged farmers. Most of the farmers belonged to mid-age (> 30 years) group with at least a decade experience in farming, be it practicing Natural Farming (NF) or the non-Natural Farming (Non-NF), who are practicing conventional/chemical farming. In Andhra Pradesh, the percent of young farmers (<30 years) practicing NF is more than that of Non-NF. This could be attributed to the promotional measures taken by the State Government. In Karnataka, the farmers practicing NF are more than the Non-NF farmers in the age group 30-50 years. However, the proportion of young farmers practicing NF is minuscule. In Maharashtra, most of the farmers practicing NF belong to the age group of 40-50 years. The distribution of farmers with respect to their age in different study states is given in Fig. 4.1.

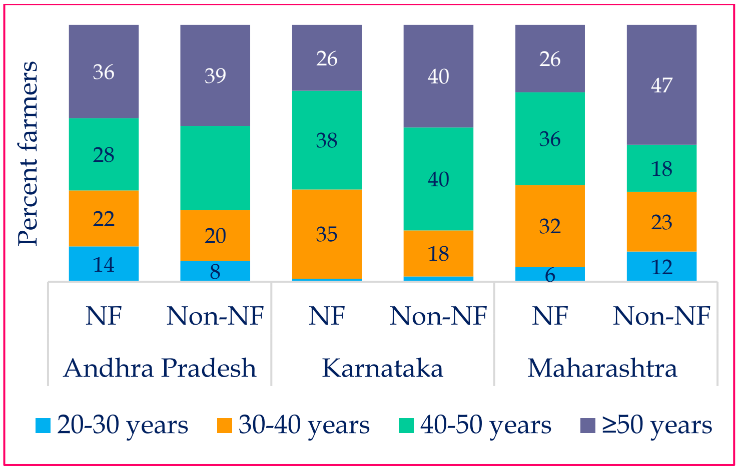


Fig. 4.1 Age of sample farmers in 3 states

Looking at the educational qualifications of the NF farmers in all the three states (Fig. 4.2), majority of them have at least intermediate education up or equivalent. However, in Karnataka, a conspicuous number of the NF farmers are graduates or above. Illiterates take a major share among Non-NF farmers compared to NF farmers in all the three states.

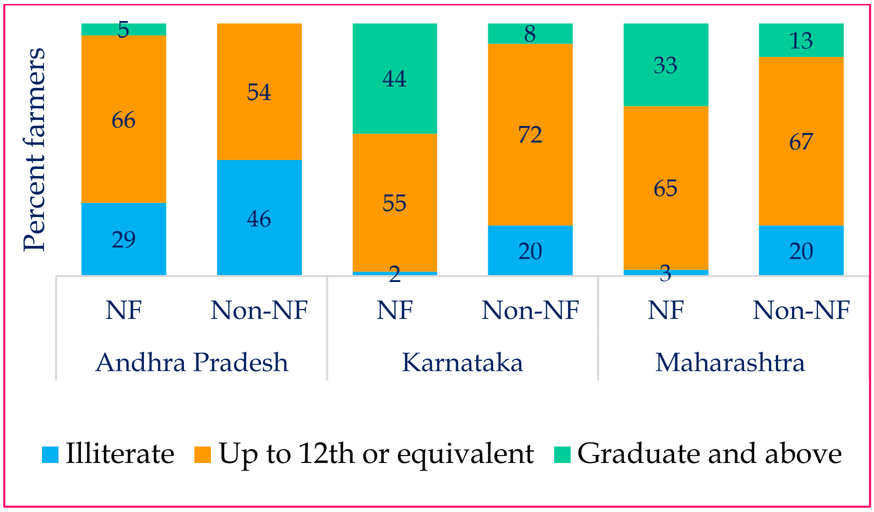


Fig. 4.2 Educational qualification of sample farmers

The average family size of the sampled farmers in all three states is found to be between 4-6 and the number of members engaged in farming is between 2-3 in each family. The average family size and the average number of family members engaged in farming for all three study states is given in Fig. 4.3.

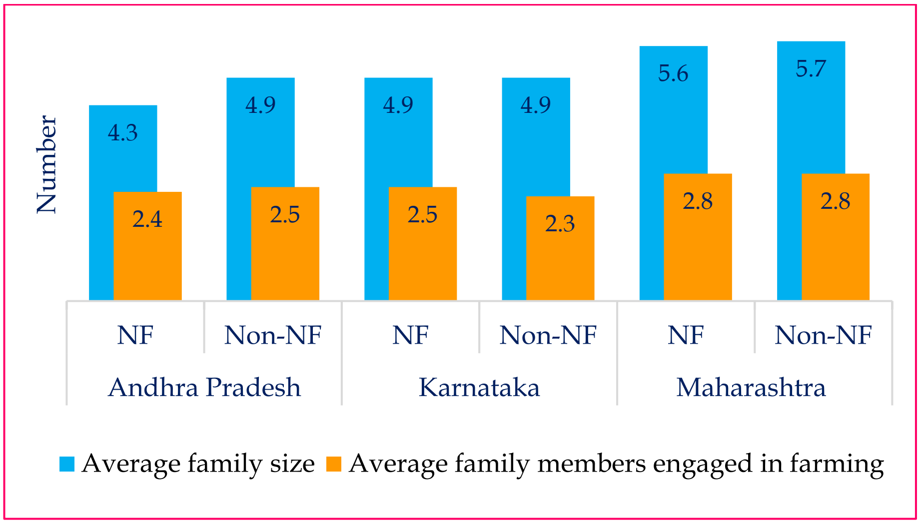
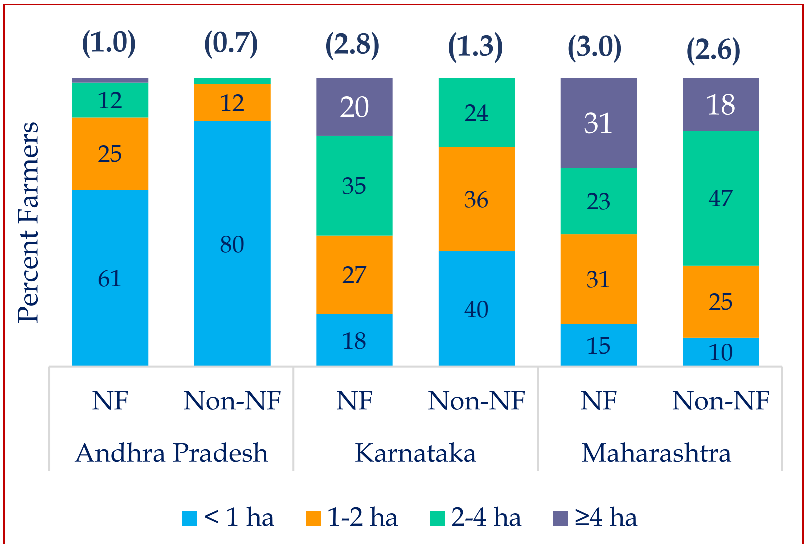


Fig. 4.3 Family size of sample farmers

Fig. 4.4 depicts the average landholding of sample farmers in the three study states. The sample farmers in Maharashtra has highest average landholding followed by Karnataka and Andhra Pradesh for both NF and non-NF categories. The average landholding of the farmers in Andhra Pradesh is less than 1 hectare which indicates that the farmers are mainly belonging to the marginal category. While proportion of marginal farmers is highest, that of small and medium farmers is more among NF farmers than among Non-NF farmers. In Karnataka and Maharashtra, a conspicuous size of the NF farmers found to be large farmers.

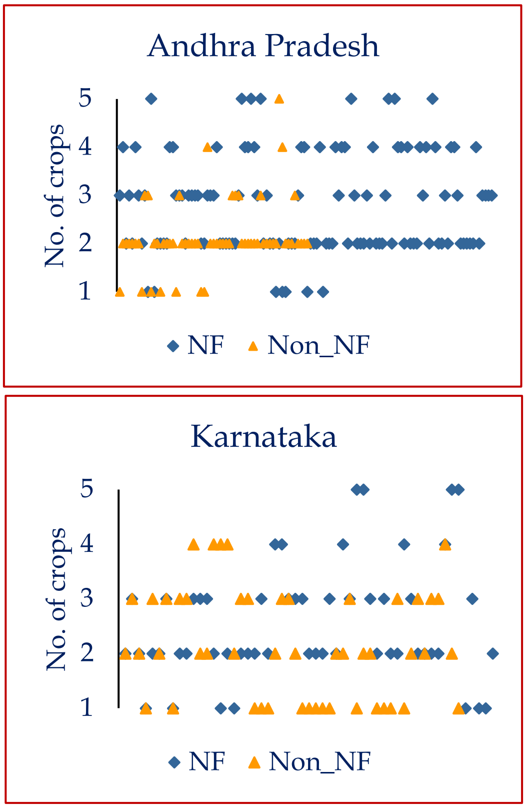


(Figures within brackets are average landholding in hectares)

Fig. 4.4 Landholding pattern of sample farmers

4.2 Cropping pattern

The study area comprised of different agro-climatic zones with varied cropping patterns. Important crops such as paddy, sugarcane, soybean, blackgram, sesamum, finger millet and several vegetable crops were found to be cultivated. Perennials like coconut, arecanut, mango, cashew and banana were also cultivated at some parts. Most of the farmers, be it NF farmer or Non-NF farmer, found to be cultivating at least 2 crops in a year. Though, few farmers are cultivating only one crop, cultivating mainly either paddy or sugarcane. As far as the crop diversification is concerned, farmers in Maharashtra were found to grow as many as 9 crops in a year. Fig. 4.5 shows the number of crops grown by the sampled NF farmers and Non-NF farmers in a year.



Intercropping is one of the major recommended practices under Natural Farming. Intercropping/ mixed cropping reduces the stress in soil by reducing the mining of only specific nutrients from the soil, as in case of solo crop. In some cases, intercrops/ mixed crops act as complement to each other in terms of nutrient cycling. However, despite its recommendation, only 29%, 45% and 17% of the NF farmers are following inter-/mixed crops in Andhra Pradesh, Karnataka and Maharashtra, respectively (Fig. 4.6 & 4.7).

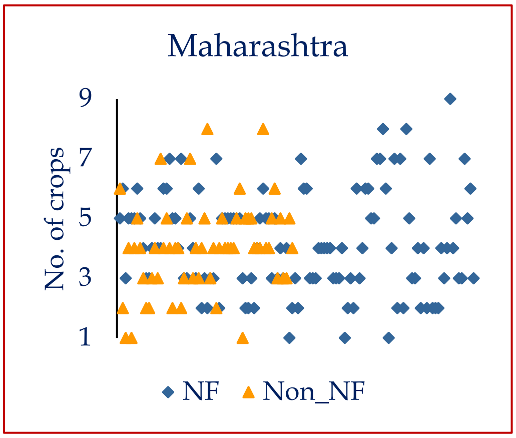


Fig. 4.5 Number of crops grown by the individual sample farmers

Fig. 4.6 Intercropping adopted by NF farmer in Karnataka

The low percentage of inter-/ mixed cropping is due to the fact that paddy is the major crop in the study area which is preferably cultivated as a solo crop. Among the study states, inter/ mixed cropping was found to be highest in Karnataka (45%). Sugarcane and the orchard crops like coconut and arecanut were found to be intercropped with pulses and vegetables. It was observed that there is almost same proportion of farmers following inter/ mixed cropping in both NF and Non-NF in Andhra Pradesh and Maharashtra. However, in Karnataka, only 10% of the Non-NF farmers found to be practicing inter/ mixed cropping, majority of whom are paddy farmers.

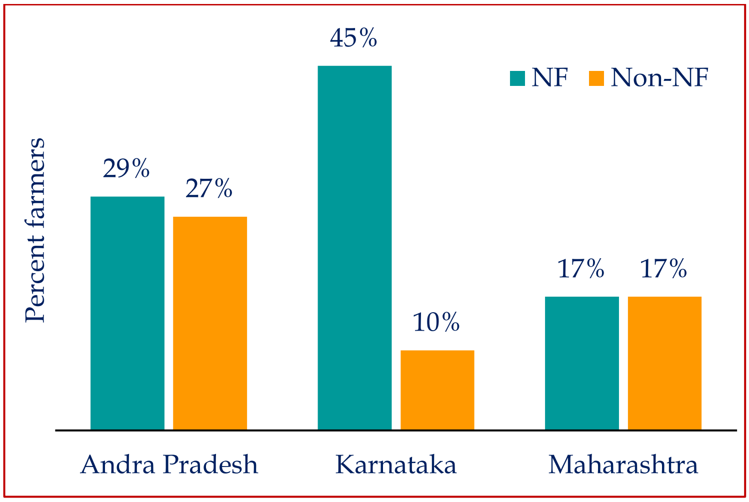


Fig. 4.7 Percentage of sample farmers following mixed/intercrop

Fig. 4.8 gives the percent area and percent number of sample farmers cultivating different crops in Andhra Pradesh. Ninety-eight percent of the sample farmers are cultivating paddy as a sole crop, which is the staple food crop in the region. It is followed by sugarcane, black gram, sesamum, cashew and mango. Black gram is grown both as a solo crop and as an intercrop with sugarcane, green gram and vegetables. Area-wise also, paddy stands first followed by sugarcane, black gram, cashew, mango and sesamum. Sesamum is cultivated by 16% farmers, though cultivated only in 4% of the area. The other crops like green gram, groundnut, jowar and millets are cultivated in about 19% of the area. Paddy is the major kharif crop followed by black gram and/or green gram in rabi. Since majority of the area is rainfed, summer crops are usually not taken and the land is left fallow.

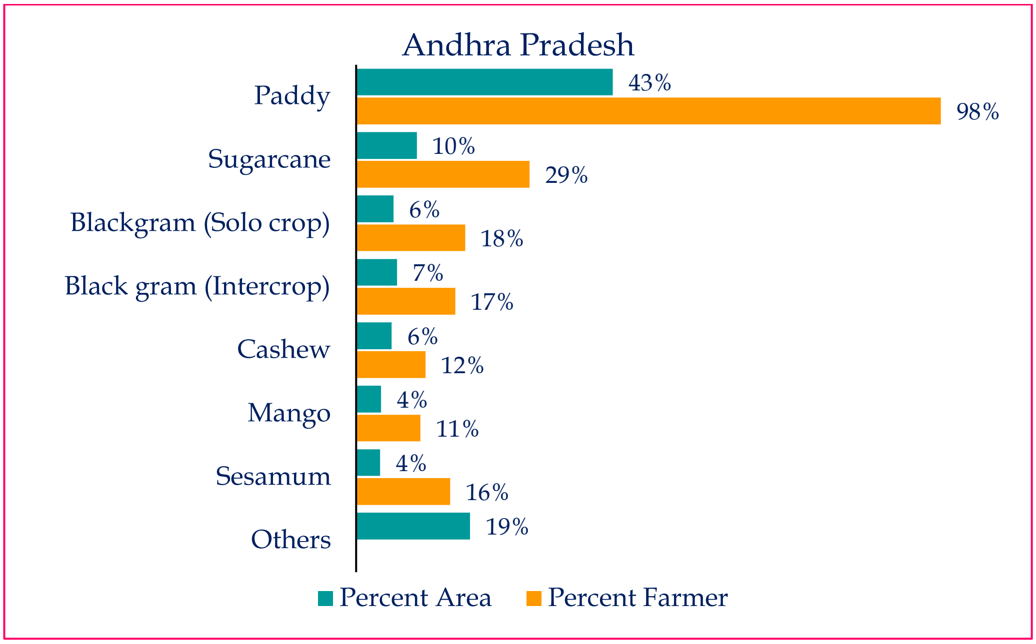


Fig. 4.8 Cropping pattern of NF farmers in Andhra Pradesh

In Karnataka, paddy is the major crop cultivated by 76% of the sample NF farmers followed by sugarcane, finger millet, banana, arecanut, tamarind and mango (Fig. 4.9). When it comes to area, again paddy stands first followed by sugarcane and banana (20% each). Both sugarcane and banana are grown as solo crop as well as intercrops. Sugarcane is intercropped with pulses like cowpea and vegetables like lady's finger, brinjal, etc. Lady's finger, drumstick, papaya and similar crops are also grown as border crops in sugarcane plots. Whereas, banana is intercropped with vegetable crops and also in coconut and arecanut orchards. These crops help earn regular income all through the year. Since there is good water availability throughout the year from canals, paddy is taken up in all three seasons. Finger millet is cultivated in summer following paddy or intercropped in the orchards of arecanut and coconut. Other crops like drumstick, papaya, lemon, medicinal plants, millets, field bean, chilli, groundnut, pigeon pea, etc. constitute 25% of the cropped area.

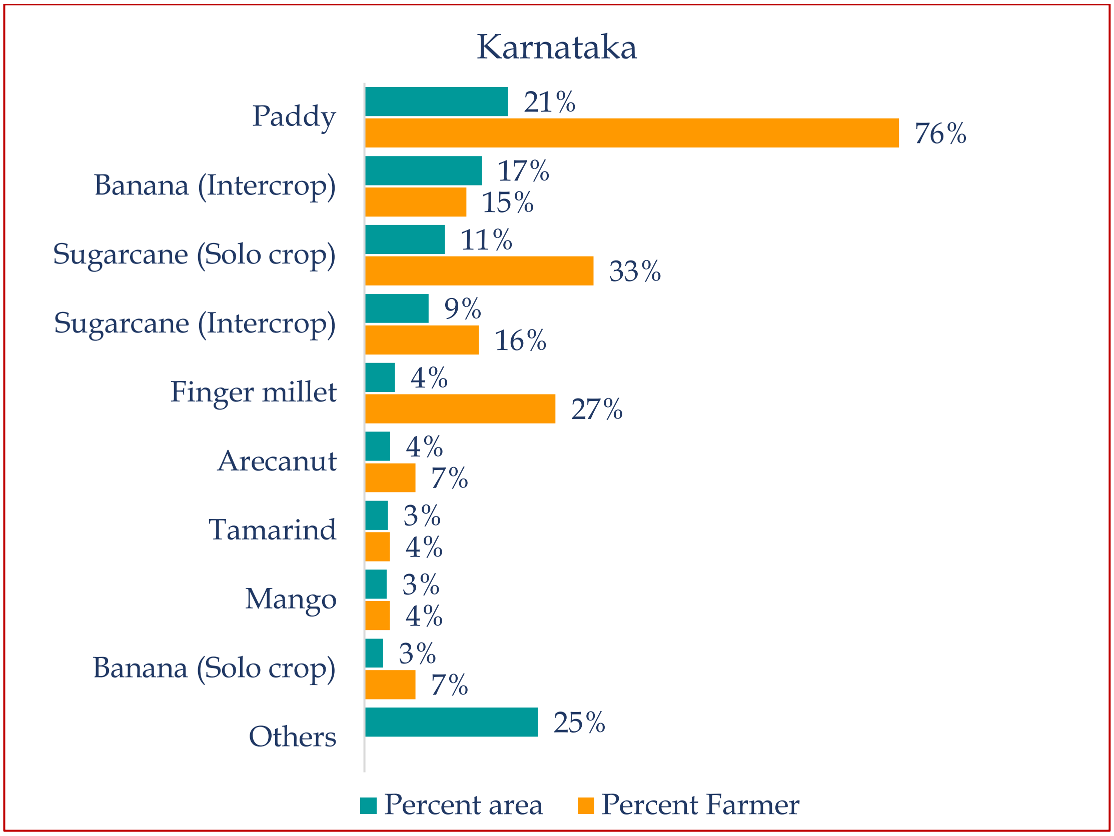


Fig. 4.9 Cropping pattern of NF farmers in Karnataka

Jowar, being the staple food crop in the study region, stands first as far as the number of NF farmers are concerned in Maharashtra. It is followed by soybean, turmeric, chickpea, wheat, cotton, green gram, pigeon pea, black gram and sugarcane (Fig. 4.10). Area-wise, soybean stands first followed by jowar, chickpea, turmeric, wheat, cotton, green gram, pigeon pea, black gram and sugarcane. Most of the crops are grown alone as solo crops. However, pigeon pea is found to be intercropped with soybean.

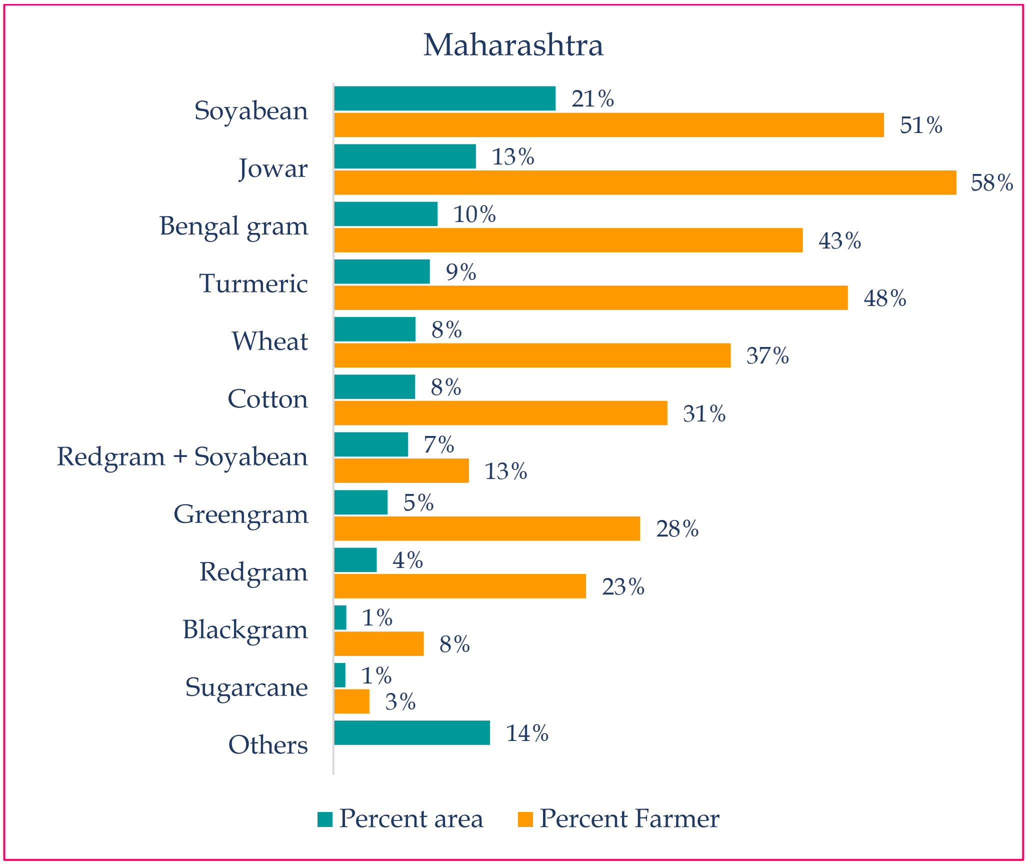


Fig. 4.10 Cropping pattern of NF farmers in Maharashtra

4.3 Livestock ownership pattern

Indigenous cow is the fundamental part of Natural Farming. The dung and urine of the indigenous cow are essential in preparing *jeevamritha* and *beejamritha*, which are the two major components of Natural Farming. The indigenous cow breeds found in the study area are Hallikar, Malnad Gidda and Gir. On an average, each farmer's household has 3, 3 and 2 indigenous cows in Karnataka, Maharashtra and Andhra Pradesh, respectively (Fig. 4.11). The population of indigenous cows among NF farmers was found to be highest compared to crossbred cows, bullocks and buffaloes in all the three study states (Fig. 4.12). Ninety-one percent of sample farmers in Karnataka have at least one indigenous cow followed by Maharashtra and Andhra Pradesh.

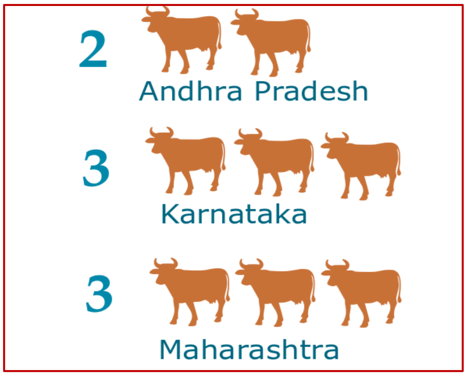


Fig. 4.11 Average no. of indigenous cow per household

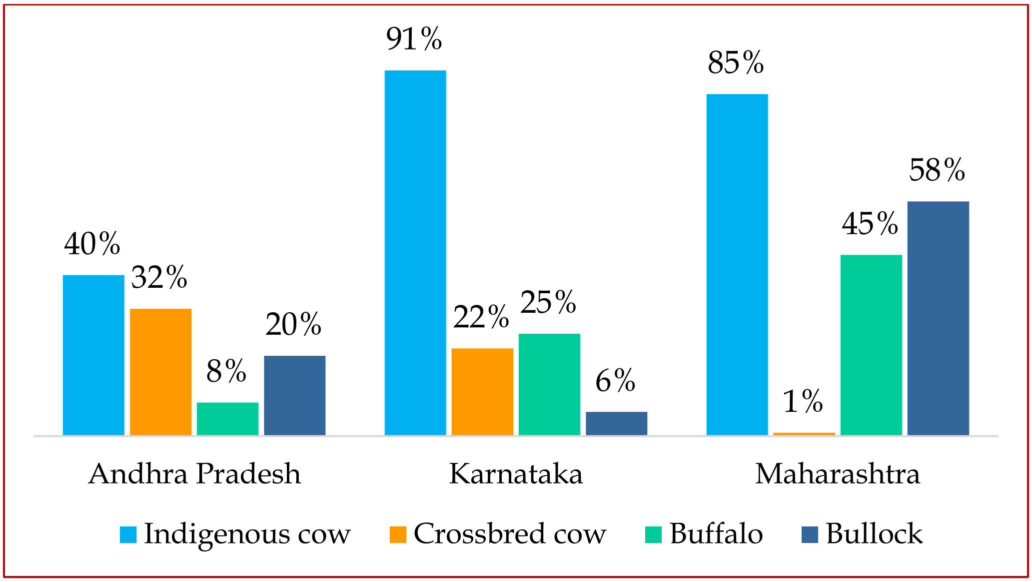


Fig. 4.12 Percent NF-farmers owning different types of livestock

4.4 Experience of practicing Natural Farming

Farmers in some parts of the country are practicing natural farming since several decades, though it has gained popularity recently. Among sampled farmers, 27% of NF farmers in Karnataka were found to be practicing NF since more than 10 years (Fig. 4.13). In Maharashtra, most of the NF farmers (66%) have experience of 3-6 years. Whereas in Andhra Pradesh, most of the NF farmers are new to this practice where 85% of them have an experience of <3 years. It clearly indicates that the farmers in Karnataka (27%) are happy with the produce grown with Natural Farming practices. These farmers are able to sell their natural products directly to the final consumers.

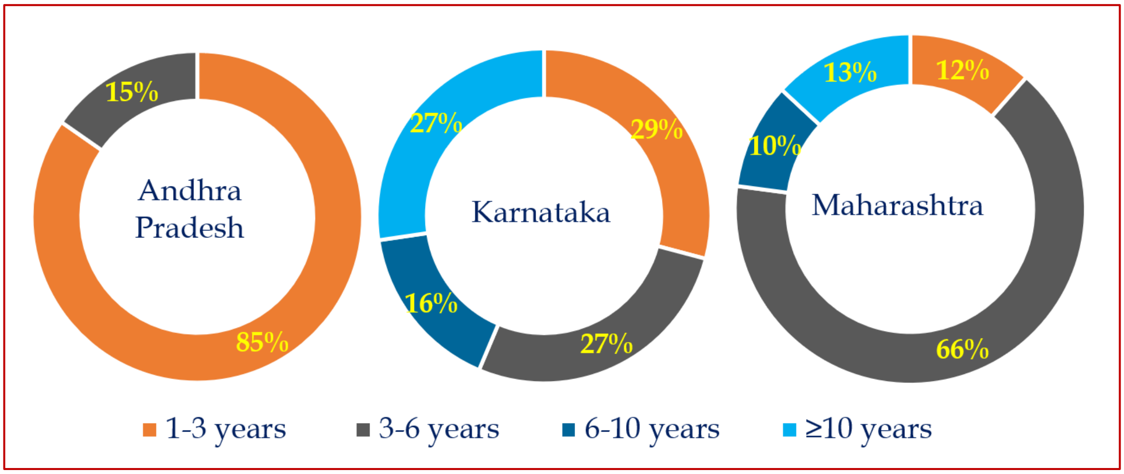


Fig. 4.13 Experience of practicing natural farming by the sample farmers

4.5 Customization in Natural Farming practices

There are lots of variations in NF practice being followed by sample NF farmers. As use of *jeevamritha* was the criteria for selection of NF farmers, all the farmers can be found to be using *jeevamritha* (Fig. 4.14). In Andhra Pradesh, a solid form of *jeevamritha* called as *ghanajeevamritha* is used by the farmers. The farmers apply *ghanajeevamritha* before sowing in the field. The *ghanajeevamritha* is prepared using the same components of *jeevamritha* except water. It is stored for several months to be used as dry form in the field. Beejamritha for seed treatment is used depending on the crop as well.

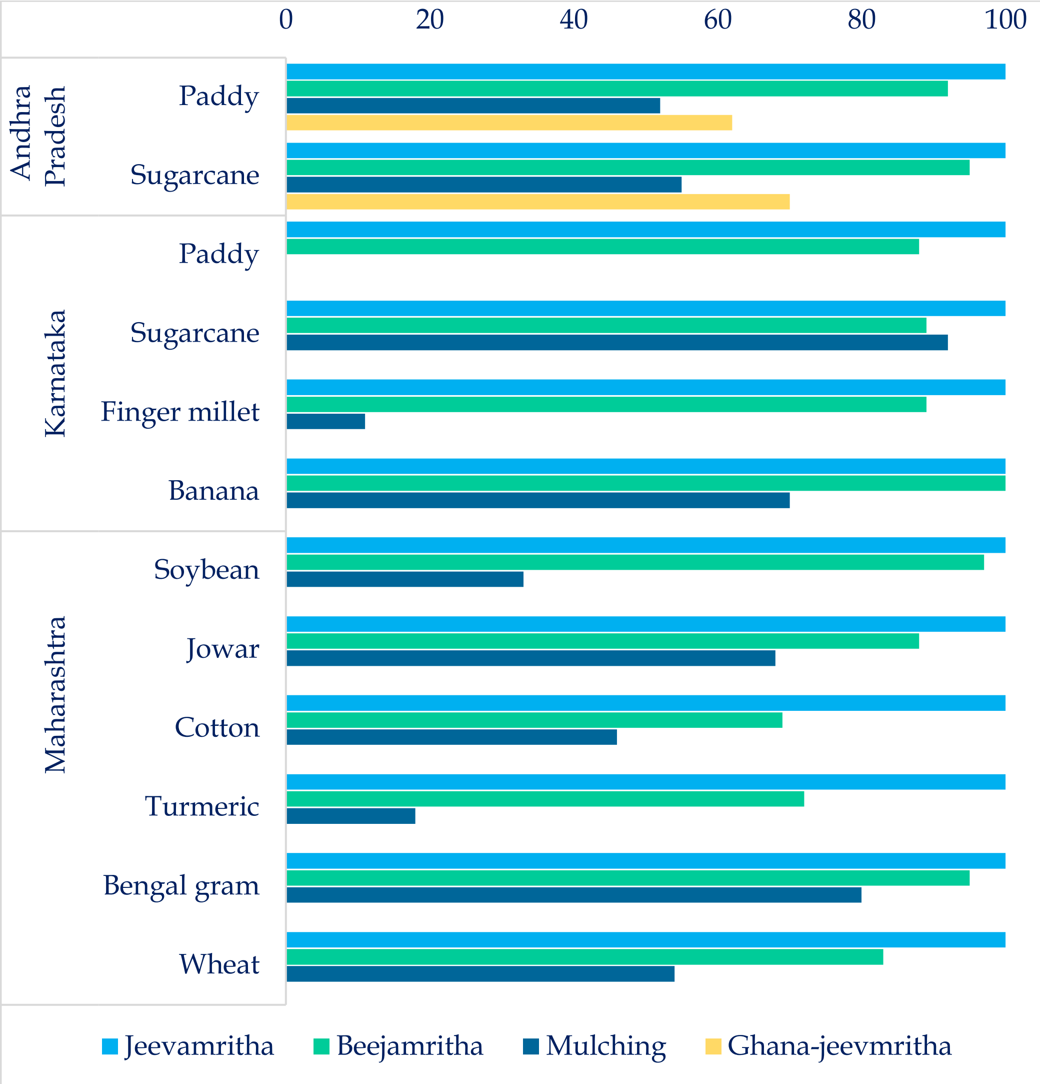


Fig. 4.14 Application of different components by NF adopter-farmers

There is no fixed quantity of *jeevamritha* used in the field. Farmers in Karnataka are found to be using more quantity of *jeevamritha* than other state farmers. It is as high as 3000 litres in Paddy (Fig. 4.15). It was also found that farmers who are using farm yard manure (FYM) in the field are applying less quantity of *jeevamritha*. Contrary to this, as farmers in Andhra Pradesh are using *ghanajeevamritha*, the quantity of *jeevamritha* used by farmers who are not applying FYM in the field is less. The quantity of *ghanajeevamritha* is around 500 kg which is applied in the field by simply broadcasting before sowing.

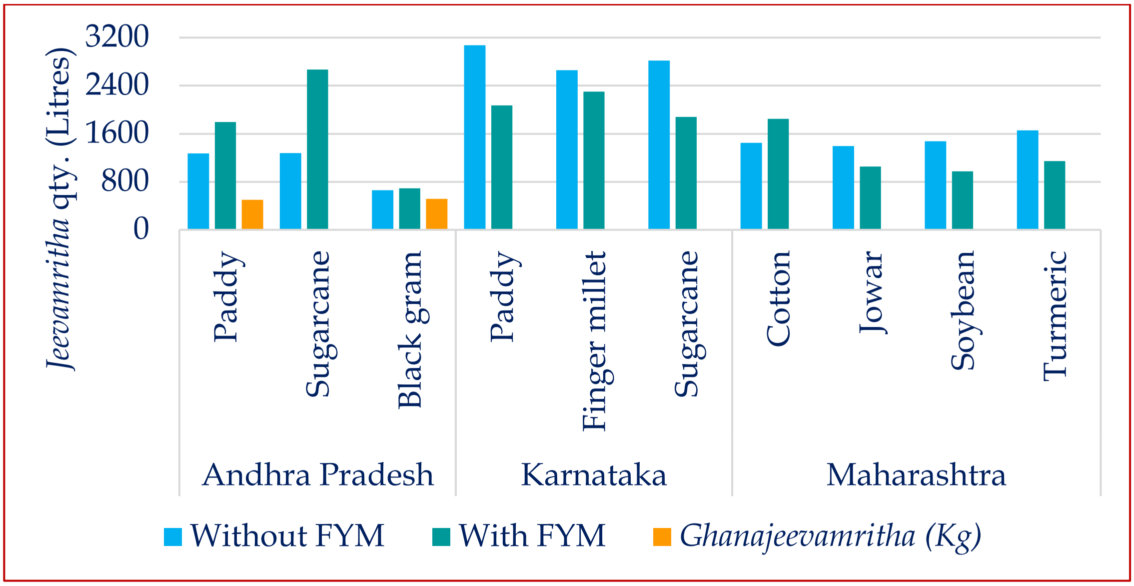


Fig. 4.15 Quantity of *Jeevamritha* applied by NF adopter-farmers

NF practice does not advocate use of FYM in the field. But it was found that NF farmers are applying FYM in the field before sowing. In Andhra Pradesh, 52% farmers are using FYM in all the crops whereas only 36% are not using in any crop (Fig. 4.16). Rest 12% farmers are using FYM in selective crops like sugarcane, paddy. In Maharashtra, more than 52% NF farmers were found to be not using FYM in their field. Twenty percent farmers were using FYM in selective fields. Sugarcane, being high-value crop, more than 80% sugarcane growing NF farmers in Andhra Pradesh and Karnataka are applying FYM in sugarcane field. In Maharashtra, 63% turmeric growing NF farmers are found to be applying FYM in turmeric field (Fig. 4.17)

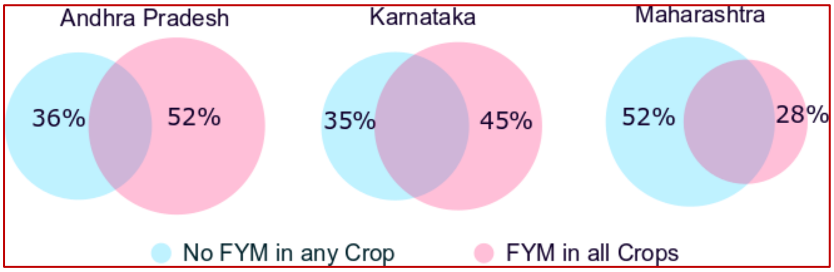


Fig. 4.16 Application of FYM by NF adopter-farmers

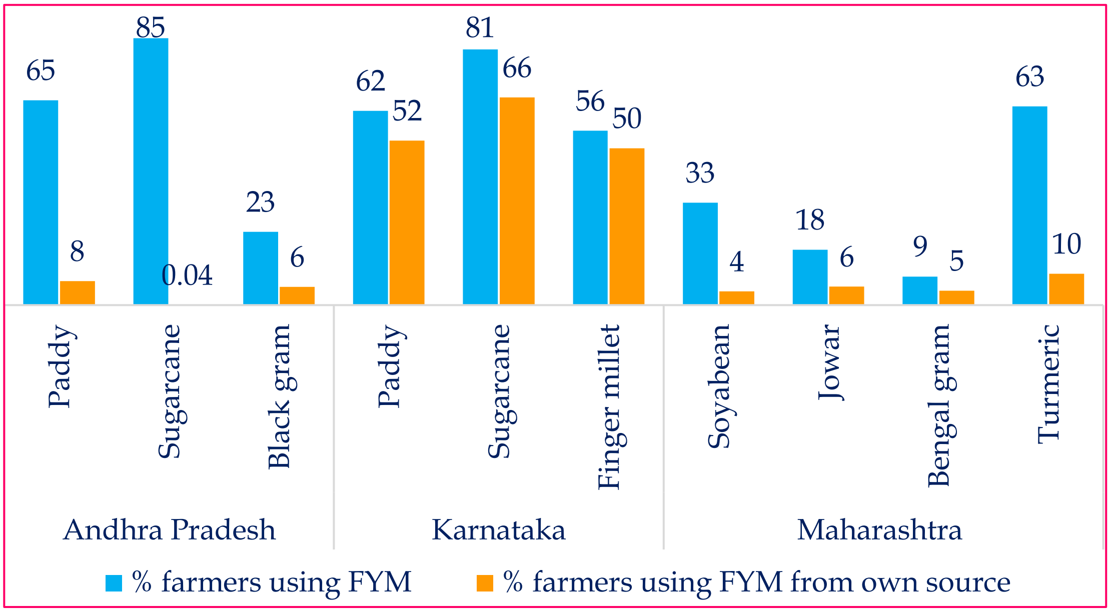


Fig. 4.17 Crop-wise application of FYM used by NF-adopters

Mulching, an important component of NF, is found to be followed by the farmers depending on the crops as wells as availability of mulching material. Farmers in Andhra Pradesh are using azolla for mulching in paddy, which was not observed in Karnataka. Live mulch crops like cow pea, other farm waste, straw, sugarcane/coconut trash are some of the mulching materials used by the farmers as mulching material (Fig. 4.18)

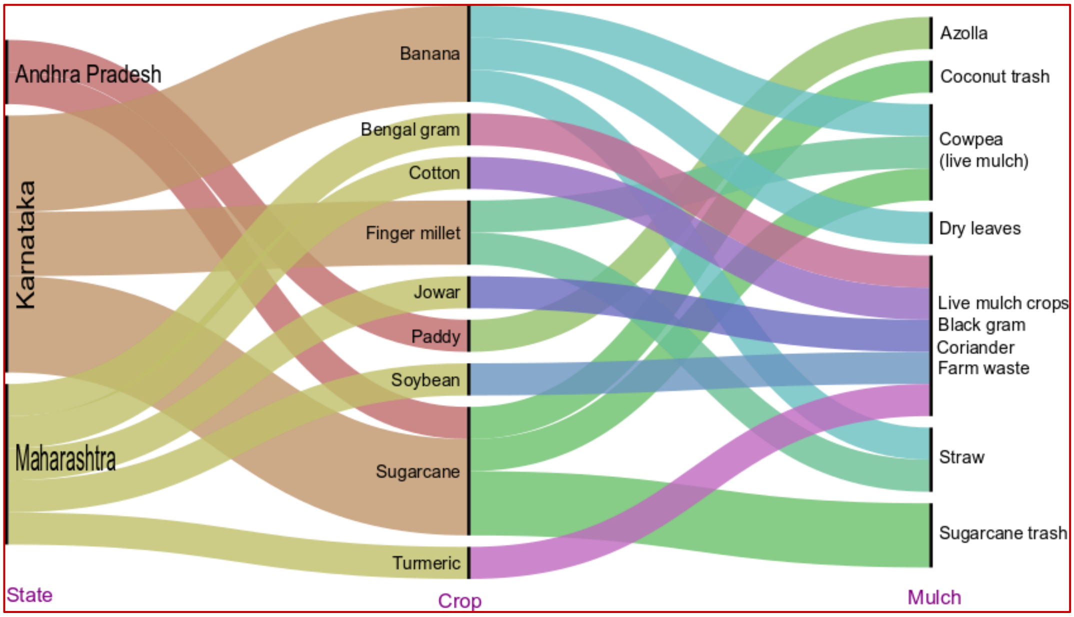


Fig. 4.18 Mulching material used in various crops

5. Available Nutrients in Soil and Plant Samples from the Fields

Maintenance of soil health (chemical, biological and physical) at its optimum level is essential for sustainable crop production and rational use of natural resources without jeopardizing their quality. Appropriate soil and crop management practices can improve/maintain various chemical (plant nutrients, acidity, salinity, sodicity, salt concentrations, etc.), biological (bacteria, fungal, actinomycetes population, etc.) and physical (infiltration, bulk density, permeability, porosity, soil moisture, etc) properties of soil up to their optimum levels to ensure the higher crop yields and sustainability (Srinivasarao et al., 2017; Indoria et al., 2016; Sharma et al., 2014).

Various soil-crop management practices are believed to improve crop yield and overall soil health in different agro-ecological regions. Natural farming is also one of such practices that may improve soil health and crop productivity. To test this hypothesis, the research team from ICAR-CRIDA (Fig. 5.1) visited selected farmers' fields in Andhra Pradesh (Visakhapatnam and Vizianagaram districts), Karnataka (Mandya and Tumkur districts) and Maharashtra states (Hingoli and Parbhani) and collected soil and plant samples from both sets of fields- natural farming and conventional farming.

Fig. 5.1 ICAR-CRIDA scientists interacting with the farmers and state government officials in Andhra Pradesh

5.1 Protocol for selection of soil and plant samples

For collection of soil and plant samples from the farmers' fields, following broad criteria were made for the better comparison of (i) natural farming adopted practices (NF) and (ii) conventional farming practices (Non-NF):

- The type of the soil to be sampled for both the practices i.e., natural farming adopted practices and conventional farming practices should be same.
- The crops/cropping system grown under both natural and conventional farming practices should be same.
- The practices of natural farming should be carried out more than 2-3 years in the same piece of land.
- For the plant sampling, both natural and conventional farming practices should have the same crops/cropping system with more or less same growth stage.

5.1.1 Collection of soil and plant samples and analysis

The ICAR-CRIDA team visited the farmers' fields of Visakhapatnam and Vizianagaram districts of Andhra Pradesh, Mandya and Tumkur districts of Karnataka, and Hingoli and Parbhani districts of Maharashtra, interacted with the farmers and collected composite soil samples from the fields of both natural and conventional farming practices after the harvest of crop during April and May, 2019, labeled them properly and brought to ICAR-CRIDA laboratory for air drying, processing and analysis of chemical parameters like organic carbon, available N, P, K, calcium, magnesium, sulphur, available micronutrients (iron, manganese, copper, zinc and boron). Standard protocol for soil analysis is given in Annexure 1. Another set of samples were collected and immediately kept in ice bags for microbial analysis. Again, during the end of August month, ICAR-CRIDA team visited the farmers' fields of Visakhapatnam and Vizianagaram districts of Andhra Pradesh to observe the condition of the standing crops, collected the plant and *jeevamritha* samples, interacted with farmers and other district officials. Likewise, during the first week of December, the team visited farmers' fields of Parbhani and Hingoli districts of Maharashtra to observe the condition of the standing crops, collection of the plant and *jeevamritha* samples and interacted with farmers. The natural farming and conventional farming plots were identified as told by the farmers and state officials. All the samples were analyzed in triplicate.

5.1.2 Protocol of measurements for plant nutrient concentration

Collected plant samples (for paddy, aboveground whole plant at 40-50 days after transplanting; for sugarcane, leaf samples of almost 120-130 days after planting; for sorghum, above ground biomass at harvest stage; and for turmeric, leaf samples of almost maturity stage, were oven-dried, finely ground and digested by wet digestion method. The contents of different plant nutrients were computed. Nitrogen concentration (%) in the plant samples was determined by micro-Kjeldahl distillation method after destroying the organic matter by H_2SO_4 and H_2O_2 (Piper, 1966). For the estimation of phosphorus, plant samples were digested with a di-acid mixture comprising of HNO_3: $HClO_4$ in the ratio of 3:1. Phosphorus concentration in the diluted di-acid digest was determined by developing yellow colour with Barton's reagent. The intensity of yellow colour was determined by using UV-VIS spectrophotometer at 420 nm (Piper, 1966) and expressed as percent. Potassium concentration in the diluted di-acid digest was determined by using flame photometer (Systronic make) and expressed as percent (Piper, 1966). Concentrations of micro-nutrient (Fe, Cu, Zn, Mn) in the diluted di-acid digest were determined by using Atomic Absorption Spectrophotometer following the method outlined by Lindsay and Norvell (1978). Boron in plant samples were determined by DTPA-Sorbitol extraction method (Miller *et al.,* 2001).

5.1.3 Protocol for enumeration of soil microorganisms

Soil dilution spread plate technique was used to record the important groups of soil microorganisms such as bacteria, fungi, actinomycetes, free-living nitrogen-fixing bacteria, phosphorus solubilizing bacteria, *Pseudomonas* sp. and *Trichoderma* sp. on media such as Nutrient Agar (Seeley *et al.*, 1991), Rose Bengal Agar (Martin, 1950), Kenknight agar (Kenknight and Muncie, 1939), Jensen N-free agar (Jensen, 1942), Pikovskaya Agar (Pikovskaya, 1948), King's B Agar (King *et al.*, 1954) and *Trichoderma* selective medium (Saha and Pan, 1997), respectively. Soils (10 g) were suspended in sterile water blanks (90 ml), after making necessary dilutions, 0.1 ml of the suspension was spread on the surface of the media plates. The plates were incubated at 28 ± 2˚C for bacteria, free-living nitrogen-fixing bacteria, *Pseudomonas* sp. (2-3 days) and fungi, phosphorus solubilizing bacteria (4-6 days) and for actinomycetes (7-10 days). After the incubation period, the colony forming units (CFU) were counted and expressed as CFU g^{-1} of soil. In case of Pikovskaya Agar, formation of clear halo around the colonies was an indication of inorganic phosphate solubilization, such colonies were counted and expressed as colony forming units per gram of soil.

5.2 Results of the analysis of samples from Andhra Pradesh

5.2.1 Background of the study area in Andhra Pradesh

(i) The study area (Vizianagaram and Visakhapatnam districts) is located near or around Araku valley and was rich in ecological diversity. The soil types of the study area were black, mixed black and red and mixed red.

(ii) The study area was under low chemical input agricultural practices;

a) Application of chemical fertilizer dosage (mostly N, P and K) were lower than the recommended dosage (40-50% of the RDF).

b) Chemical methods of weed control were almost nil.

c) Only 25-35% farmers were using the chemical method of disease and pest control.

d) Farmers were applying 1-2 t ha^{-1} FYM in paddy and 2-4 t FYM ha^{-1} in sugarcane at every/alternative year(s).

e) Most of the area (80-90%) was irrigated by bore wells, open wells, canals, etc.

5.2.2 Comparison of adopted practices under natural and conventional farming

A broad comparison of some of the ongoing farming practices being adopted under natural farming and conventional farming is shown in Fig. 5.2 and given in Table 5.1. In the study area, some of the NF farmers were applying *Ghanjeevamritha* @ 0.5-1.0 t ha^{-1}; remaining farmers (40-50%) were applying FYM @ 1-2 t ha^{-1} in paddy and 2-4 t ha^{-1} in sugarcane crop. Throughout the cropping season, the requirement of labour was quite high in natural farming adopted practices for making and spraying of different formulations in the field such as *Jeevamritha, Beejamritha, neemastra, brahmastra, agniastra*, etc. Labour is also required for making the *Ghanjeevamritha* i.e., collection of cow dung and urine + mixing of these ingredients + making the balls + drying under shade for 10-15 days+ application in the field.

Jeevamritha ready for application after fermentation for 10-15 days

Green manuring by *dhaincha* crop adopted by both NF and Non-NF farmers

Ghanajeevamritha preparation by NF farmers

Soil–water paste applied on maize crop to control the stem borer and caterpillar by NF farmers

Fig. 5.2 Different practices followed by the NF- farmers in the study area

The observations on Natural Farming adopted practices (*Jeevamritha, Beejamritha, Acchadana/Mulching and Whapasa/*irrigation) in study area are as follows:

(i) *Jeevamritha*: Most of the Natural Farming adopting (NF) farmers (≈100%) were applying *jeevamritha.*

(ii) *Beejamritha:* 40-50% of NF farmers treated their crop seeds with *Beejamritha*.

(iii) *Acchadana/Mulching*-Three types of mulching have been suggested under Natural Farming (Table 5.2).

(iv) Under ZBNF, it is recommended to irrigate the field only at noon, where there are both air molecules and water molecules present in the soil. The irrigation is to be applied in alternate furrow which helps in significantly reducing the irrigation requirement. However, no such practice was found *Wapasa:* in the field under NF.

Table 5.1 Practices followed by the sample farmers in Andhra Pradesh

Practices	Natural farming adopted practices	Conventional farming practices
Mulching	Sugarcane field with sugarcane trashes.	-same-
Green manuring	With dhaincha, sunhemp and other pulse crops.	-same-
Farmyard manure	Farmyard manure and/or *ghanJeevamritha.*	Only farmyard manure.
Jeevamritha	Application at every 15 days intervals.	Nil
Chemical Fertilizer	Nil	Lower dose of chemical fertilizers.
Tillage practices	Tillage practices were same as Non-NF.	Tillage practices were same.
Azolla application	In paddy fields	-same-
Weed control	Mostly manual weeding.	-same-
Pests and diseases control	• 50-60% farmers applied the *Neemastram,* spraying at every 15 to 30 days intervals. • Application of bund soil-water paste.	About 50-60% farmers were using chemical methods of disease and pest control.

Table 5.2 Types of mulching suggested under NF and actual practices going on in the NF fields

Recommended mulching practices under NF	Descriptions	Actual practices in field
Soil Mulch	Deep ploughing should be avoided to protect topsoil; it enhances aeration and water retention in the soil.	Tillage practices were same under both NF and Non-NF.
Straw Mulch	Dried waste biomass of previous crops.	Sugarcane trashes mulching was very common in sugarcane crop under both NF and Non-NF.
Live Mulch	Multiple cropping patterns of monocot and dicot in the same field. Dicot fix the atmospheric N and monocot add the potash, phosphate and sulphur in the soil.	Paddy and sugarcane are grown as monocrop under both the farming i.e., NF and Non-NF. Upland paddy intercropped with pigeonpea, at few locations under both the farming.

All the four components of the Natural Farming (NF) i.e., (i) Jeevamritha, (ii) Beejamritha, (iii) Acchadana/Mulching and, (iv) Wapasa was not incorporated in time sequence by NF farmers. Most of the farmers were applying only jeevamritha but didn't focus on other components of the natural farming.

5.2.3 Farming practices adopted by sample farmers in paddy in Vizianagaram district, Andhra Pradesh

Different farming practices adopted by different farmers in all the selected villages in Vizianagaram district are given in Annexure III.

5.2.3.1 Availability of soil organic carbon and soil nutrients status in paddy fields in Vizianagaram district, Andhra Pradesh

The soil sample from one paddy farmer's field each under Natural farming and conventional farming in 11 villages of Vizianagaram district was collected for analysis of available soil nutrients. The results related to average of all the sample plots in terms of soil organic carbon (SOC) and soil nutrients status under both the practices in Vizianagaram district (AP) are given in Fig 5.3.

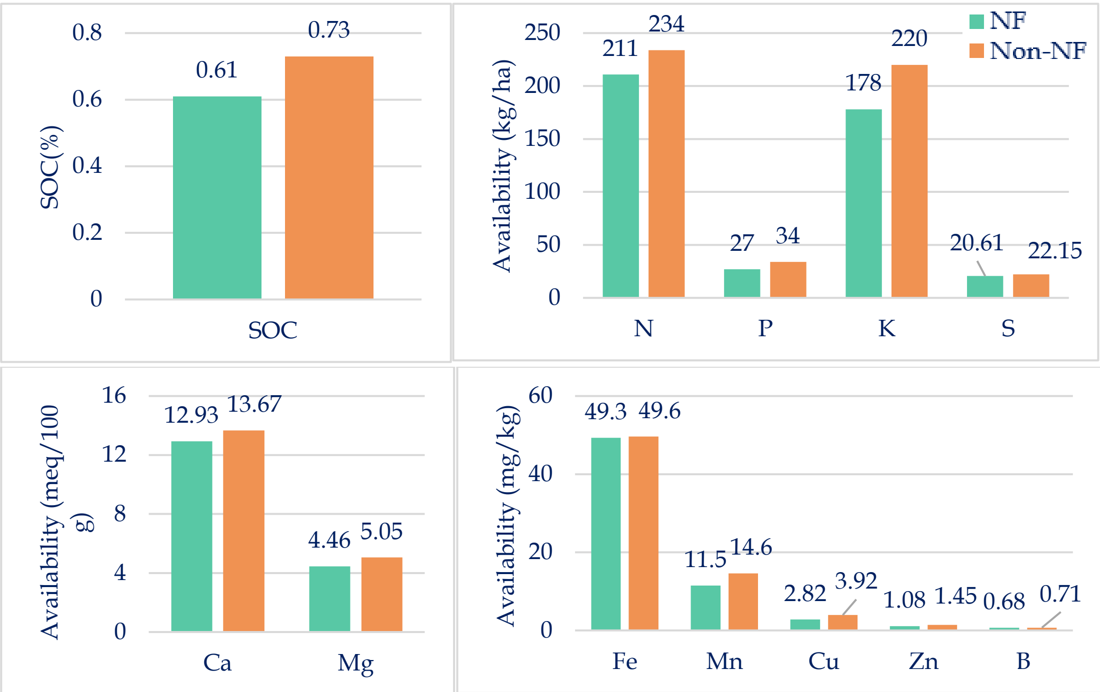


Fig 5.3 Availability of soil organic carbon (SOC) and soil nutrients in paddy cultivated fields in Vizianagaram district, Andhra Pradesh

Results showed the higher mean soil organic carbon (SOC), available macro (N, P, K, Ca, Mg, S) in conventional farming as compared to those in natural farming in paddy cultivated fields. Higher concentration of SOC in conventional practices as compared to Natural Farming may be due to higher amount of carbon input through farmyard manure and green manure applied in conventional practices. Application of N, P and K through chemical fertilizers also might have resulted into more root growth, which might have contributed to higher amount of carbon. Similarly, higher amounts of mean exchangeable Ca (12.7 meq/100 g) and Mg (7.1 meq/100g) were found in conventional farming as compared to natural farming (10.8 and 4.8 meq/100g Ca and Mg, respectively). In case of micronutrients, slightly higher amounts of mean available Fe, Mn, Cu and Zn were observed in conventional farming as compared to those in natural farming. However, in some cases, reverse results were also observed, particularly in case of micro-nutrients. In some villages, the micronutrients were observed to be higher in Natural Farming field as compared to that in conventional field. The plot/village-wise results are presented in Annexure IV(a-c).

5.2.3.2 Soil microbial population in paddy cultivated fields in Vizianagaram district

The data related to average soil microbial population in both types of farming practices (NF & Non-NF) in paddy cultivated fields in Vizianagaram (AP) are given in Table 5.3 and detailed plot-wise microbial population is given in Annexure IV(d-e). Results showed that population of different types of microbes varied across different plots. The average count of bacterial population and free-living nitrogen fixing bacteria was high in Natural farming field, while conventional farming fields recorded slightly higher mean population of fungi, phosphorus solubilizing bacteria (PSB), actinomycetes and *Pseudomonas* sp.

Table 5.3 Average soil microbial population in paddy cultivated fields in Vizianagaram district (Andhra Pradesh) (Log_{10} CFU/g soil)

Particulars	Farming Type	Range	Mean	S.D.
Bacteria	NF	8.00 - 9.41	8.72	0.40
	Non-NF	7.00 - 9.79	8.63	0.71
Fungi	NF	3.18 - 4.87	4.04	0.40
	Non-NF	3.18 - 4.86	4.09	0.52
Actinomycetes	NF	3.70 - 4.85	4.44	0.37
	Non-NF	4.00 - 4.88	4.45	0.23
Free-living Nitrogen-fixing bacteria	NF	4.00 - 5.79	5.16	0.45
	Non-NF	3.70 - 5.44	4.75	0.53
Phosphorus solubilizing bacteria	NF	2.70 - 3.65	3.27	0.32
	Non-NF	3.18 - 4.10	3.67	0.38
***Pseudomonas* sp.**	NF	5.00 - 6.65	6.14	0.43
	Non-NF	5.70 - 7.26	6.24	0.46
n=11				

Note: NF means Natural Farming field; Non-NF means Conventional Farming fields

5.2.3.3 Availability of plant nutrient contents in paddy plants in Vizianagaram district

The plant samples for plant nutrients analysis were collected from one each of NF and Non-NF from seven villages in the district. The data related to the paddy plant nutrient contents (in whole aboveground biomass at 40-50 days after transplanting) in natural farming practices and conventional farming in Vizianagaram (AP) are shown in Fig 5.4. Analysis of plant samples showed that except Cu, higher mean amount of N, P, K, Fe, Mn and Zn content were observed in conventional farming as compared to those in natural farming. Although, there were significant variations in the trend when observed for each village (Annexure IVf).

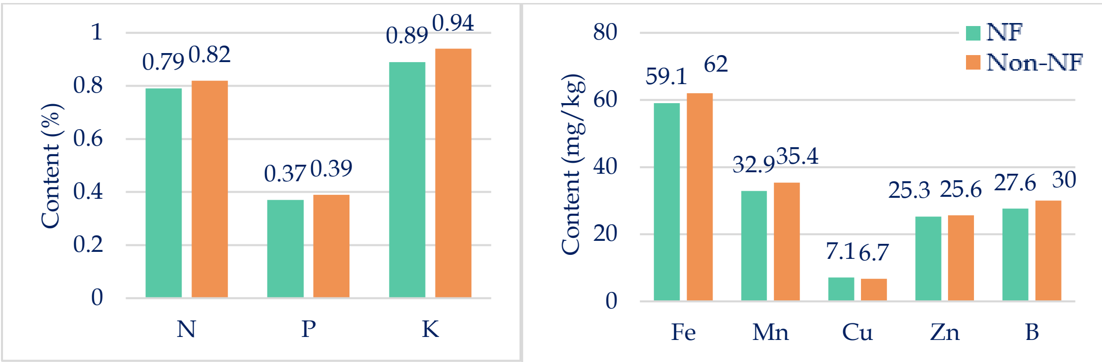


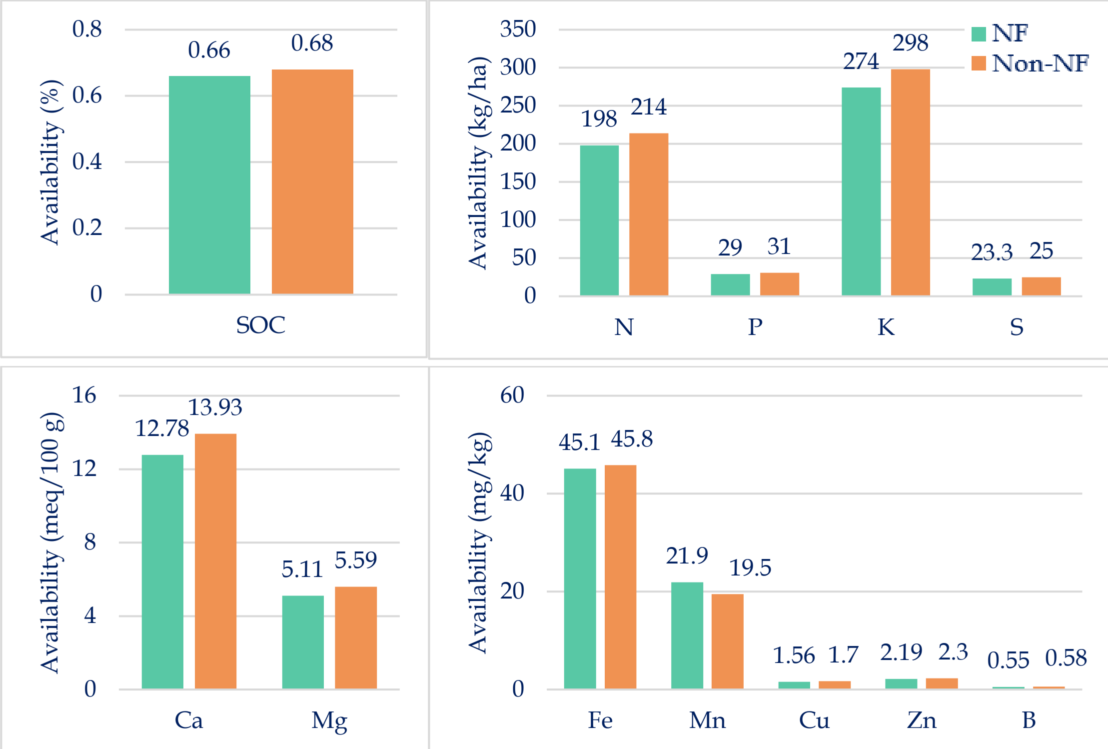
Fig 5.4 Average plant nutrient contents in paddy plants cultivated under NF and Non-NF practices in Vizianagaram district

5.2.4 Farming practices adopted by sample farmers in paddy and sugarcane cultivation in Visakhapatnam district (Andhra Pradesh)

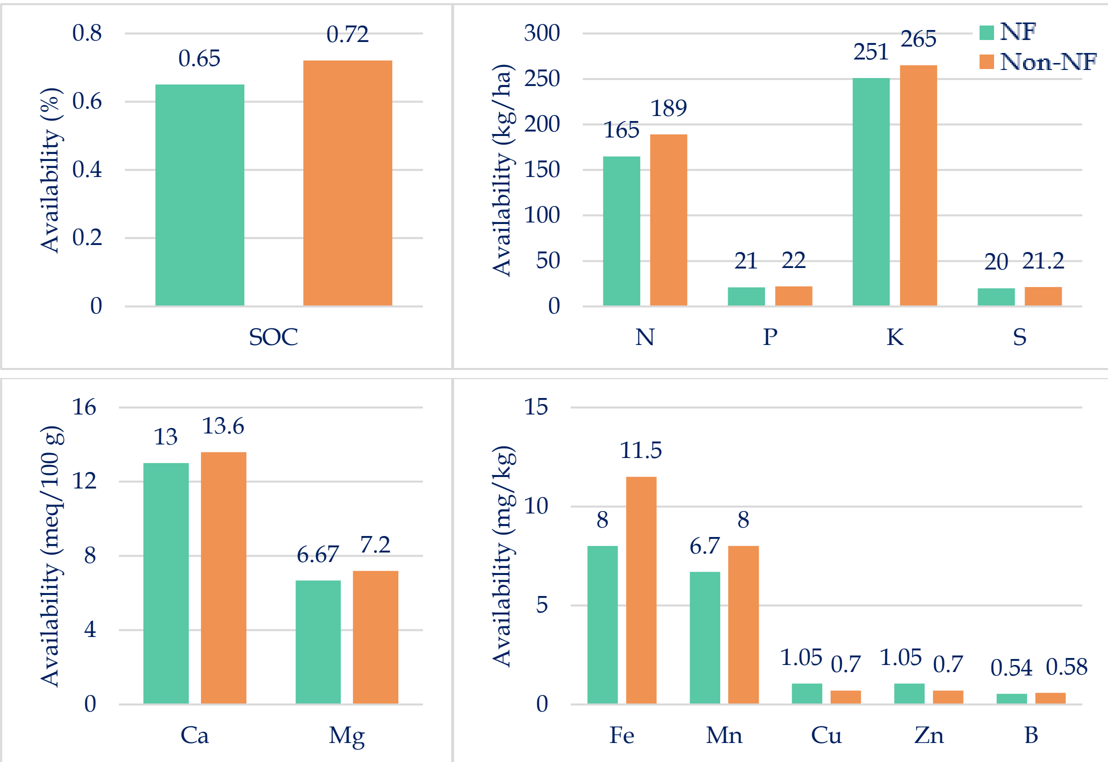
For analysis of soil samples and plant samples, one farmer each practicing natural farming and conventional farming for paddy cultivation was selected from 8 villages and for sugarcane cultivation was selected from 3 villages in Vishakhapatnam district of Andhra Pradesh state. For comparison purposes, care has been taken that both the contrasting farmers' fields have similar soil type and farmers have cultivated similar crop following different practices. The details of farming practices adopted by these sample farmers are given in Annexure V. The analysis of soil and plant samples are given below.

5.2.4.1 Availability of soil organic carbon (SOC) and soil nutrients status in paddy fields in Visakhapatnam district

The available soil organic carbon (SOC) and soil nutrients in natural farming and conventional farming practices in paddy cultivated fields in Visakhapatnam district (Andhra Pradesh) were analyzed. Average availability of different nutrients in the soil of paddy and sugarcane cultivated fields under two practices are given in Fig 5.5 & Fig 5.6. The detailed plot-wise results are given in Annexure VI(a-f).



a. Paddy (n=8)



b. Sugarcane (n=3)

Fig 5.5 Average available nutrients status in paddy and sugarcane cultivated soils under NF & Non-NF practices in Vishakhapatnam district

The data revealed that comparatively higher mean soil organic carbon (SOC) was observed in conventional farming of paddy as compared to that in natural farming. In these areas, paddy and sugarcane based systems are the major cropping systems that require higher amount of nutrients. Most of the farmers either practice green manuring or add farmyard manure regularly which adds not only macro and micro nutrients, but also add significant amount of carbon. Application of N, P and K through chemical fertilizers also helps more root growth which contributes higher amount of carbon. In paddy cultivated soils, higher amount of mean available N, P, K, exchangeable and Mg, available Fe, Cu and Zn were found in conventional farming practices as compared to natural farming practices. Slightly higher amount of mean available Mn was observed in natural farming practices as compared to conventional farming practices.

Similarly, in sugarcane cultivated soils, higher amount of mean SOC, available N, P, K, exchangeable Ca, Mg, Fe and Mn were found in conventional farming practices as compared to natural farming practices. Slightly higher amount of mean available Cu and Zn were observed in natural farming practices as compared to conventional farming practices.

5.2.4.2 Effect of NF and Non-NF practices on soil microbial population in paddy and sugarcane cultivated fields in Visakhapatnam district (Andhra Pradesh)

The data related to average soil microbial population in both types of farming practices (NF & Non-NF) in paddy and sugarcane cultivated fields in Vishakhapatnam (AP) are given in Table 5.4 and detailed plot-wise microbial population is given in Annexure VI(g-j). It is evident from the results that the population of different types of microbes varied across different plots.

For paddy, the average count of bacterial population and free-living nitrogen fixing bacteria was high in Natural farming field, while conventional farming fields recorded slightly higher mean population of fungi, phosphorus solubilizing bacteria (PSB), actinomycetes and *Pseudomonas* sp. In paddy cultivated fields, the fungi, actinomycetes, PSB and *Trichoderma* sp. were more in conventional farming fields than natural farming fields. Slightly higher population of bacteria, free living nitrogen fixing bacteria and *Pseudomonas* sp. were observed in natural farming fields. In case of sugarcane, the bacteria, PSB and *Pseudomonas* sp. were more in conventional farming fields of sugarcane in comparison with natural farming fields. Whereas, fungi, actinomycetes, free-living nitrogen-fixing bacteria and *Trichoderma* sp. were slightly higher in natural farming fields.

Table 5.4 Average soil microbial population in paddy and sugarcane cultivated fields in Visakhapatnam district (Andhra Pradesh)

(Log_{10} CFU/g soil)

Particulars	Farming Type	Paddy (n=8)			Sugarcane (n=3)		
		Range	Mean	S.D.	Range	Mean	S.D.
Bacteria	NF	8.00-9.36	8.47	0.4	8.18-8.40	8.25	0.1
	Non-NF	8.00-9.15	8.35	0.32	8.00-9.24	8.33	0.05
Fungi	NF	3.40-4.46	3.85	0.33	4.13-4.30	4.19	0.08
	Non-NF	2.70-4.59	4.00	0.63	3.90-4.34	4.07	0.19
Actinomycetes	NF	3.00-5	4.05	0.83	4.98-5.02	5.00	0.02
	Non-NF	2.70-5.11	4.14	0.87	4.18-4.90	4.65	0.33
Free-living Nitrogen-fixing bacteria	NF	4.60-5.76	5.18	0.33	5.04-5.60	5.41	0.26
	Non-NF	4.00-5.79	5.01	0.52	4.70-5.32	4.93	0.28
Phosphorus solubilizing bacteria	NF	2.70-4.15	3.48	0.45	3.54-3.74	3.64	0.08
	Non-NF	3.30-3.90	3.51	0.19	3.54-3.74	3.66	0.09
***Pseudomonas* sp.**	NF	6.18-7.10	6.51	0.27	6.00-6.54	6.24	0.22
	Non-NF	5.70-6.70	6.39	0.32	6.18-6.81	6.46	0.26
Trichoderma sp.	NF	2.54-4.11	3.18	0.42	2.00-3.41	2.72	0.58
	Non-NF	2.00-4.31	3.25	0.62	2.00-3.02	2.56	0.42

Note: NF means Natural Farming field; Non-NF means Conventional Farming fields

5.2.4.3 Plant nutrient contents in the paddy and sugarcane plants in Visakhapatnam district

The data pertaining to the average plant nutrient contents in paddy (in whole aboveground biomass at 40-50 days after transplanting) are given in Fig. 5.6 and the detailed plot-wise results are given in annexure VI(k-l). Results from the analysis showed higher mean amount of N, Fe, Mn, Cu content in conventional farming compared to natural farming. Similarly, mean P and K content were more or less same in both farming practices, while Zn was slightly higher in natural farming practices.

Analysis of leaf samples of 120-130 days old sugarcane plant showed higher amount of mean N, P, K Fe, Cu and Zn contents in conventional farming compared to natural farming (Fig. 5.7). Slightly higher amount of Mn content were observed in natural farming compared to conventional farming. The detailed plot-wise results are given in annexure VI(m-n).

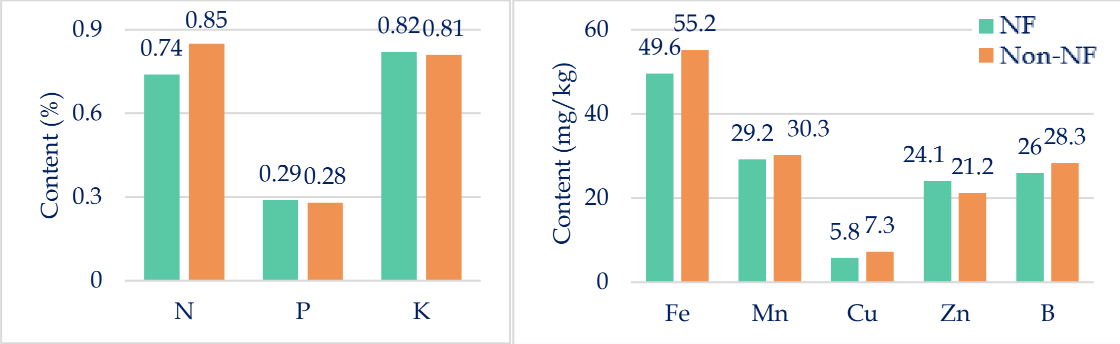


Fig 5.6 Average plant nutrient contents in paddy cultivated under NF and Non-NF practices in Visakhapatnam district

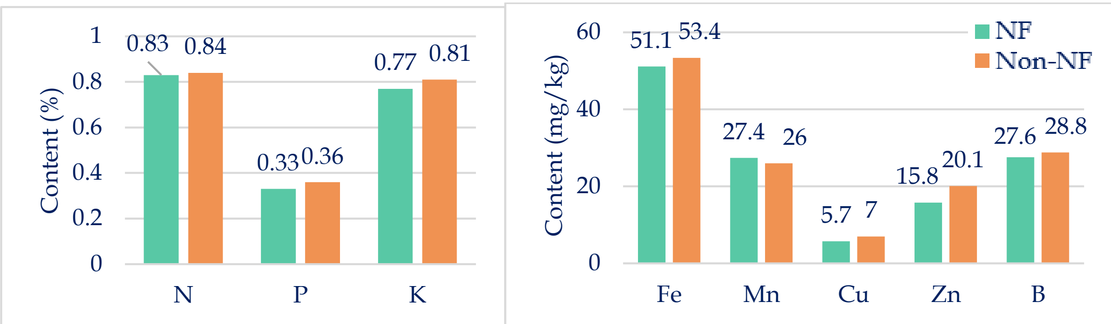


Fig 5.7 Average plant nutrient contents in sugarcane plants cultivated under NF and Non-NF practices in Visakhapatnam district

5.2.5 Nutrient & bacterial contents of jeevamritha samples collected from Andhra Pradesh

Results of the analysis of nutrient contents of jeevamritha samples (about 2 weeks after preparation) collected from 7 farmers is presented in Table 5.5. The results showed that the *jeevamritha* contains OC, N, P, K, Ca, Mg, S, Fe, Zn, Mn and Cu. In some of the samples, few nutrients viz., Ca, Zn, Mn and Cu content were below detectable range. The culturable bacterial population of jeevamritha samples ranged from 8.00-8.70 Log10CFU ml-1. The sample-wise results are given in annexure VI(o-p).

Table 5.5 Average nutrient and bacteria contents of *jeevamritha* samples collected from Andhra Pradesh

Particulars	Range	Mean	SD
OC (%)	0.19-0.28	0.24	0.032
N (%)	0.03-0.06	0.046	0.011
P (%)	0.017-0.021	0.019	0.002
K (%)	0.04-0.06	0.053	0.008
Ca (%)	0.03-0.05	0.04	0.008
Mg (%)	0.02-0.03	0.025	0.005

S (%)	0.012-0.017	0.015	0.002
Fe (mg l^{-1})	29.8-45.7	36.5	5.6
Zn (mg l^{-1})	1.6-2.1	1.8	0.2
Mn (mg l^{-1})	1.1-1.9	1.6	0.4
Cu (mg l^{-1})	1.1-1.9	1.5	0.4
Bacteria (Log10 CFU ml^{-1})	8.00-8.70	8.19	0.25
n=7			

5.3 Results of the analysis of samples from Karnataka

5.3.1 Farming practices adopted by sample farmers in paddy cultivation in Mandya and Tumkur districts (Karnataka)

The study area in Mandya district is mostly dominated by black soils. The major crops of the study area are paddy followed by sugarcane and banana. In the study area, most of the farmers are raising upland rice. The area is under full irrigation by borewells and canals. Cultivation of vegetables in between banana rows was common. Mulching in sugarcane is common practice under NF and Non-NF.

In contrast to Andhra Pradesh farmers, in this district, most of the large farmers are adopting the natural farming practices as compared to the small farmers. As farmers are expecting the low yield in natural farming adopted practices as compared to conventional farming, so the small holding farmers who are exclusively depending on agriculture for their livelihood are not following the NF practices. Under conventional farming, farmers applied FYM 1-2 t ha^{-1} in paddy and 2-3 t ha^{-1} in sugarcane crops. Farmers mostly applied the RDF in the paddy and sugarcane crop. A very few soil samples qualified the criterion made in section 1.

The study area in Tumkur district is surrounded by hills with majority of the area under horticulture crops. Major soils are red and black soils. arecanut, coconut, banana, beetlevine and black peppers are the major crops. Although some of the samples collected from this district but none of the soil samples found for comparison, hence, no data has been presented from Tumkur district. The details of farming practices adopted by the sampled farmers is given in annexure VII.

5.3.2 Availability of soil organic carbon and soil nutrients status in paddy fields in Mandya district (Karnataka)

Data pertaining to the soil organic carbon and soil nutrients status in paddy and sugarcane cultivated fields are shown in Table 5.6. Results showed that slightly higher soil organic carbon (SOC), available N, P and K in conventional farming compared to natural farming. Higher available Fe, Cu were observed in natural farming compared to conventional farming in paddy cultivated soils. Whereas, Mn and Zn values in conventional farming are slightly higher compared to natural farming. In sugarcane cultivated soils higher available K and Mn in natural farming was observed compared to conventional farming. Higher soil organic carbon (SOC), available N, P, available Fe, Cu and Zn was observed in conventional farming compared to natural farming.

Table 5.6 Availability of soil organic carbon (SOC) and nutrients in paddy and sugarcane cultivated fields in Mandya district

Crop	Paddy (n=1)		Sugarcane (n=1)	
	NF	Non-NF	NF	Non-NF
SOC (%)	0.6	0.77	0.85	0.87
N (kg/ha)	186	217	130	161
P (kg/ha)	31.6	33.2	16.9	25.4
K (kg/ha)	121	240	125	115
S (kg/ha)	22.3	27.4	27.2	26.4
Ca (meq/100g)	12.6	13.3	11.2	12.3
Mg (meq/100g)	5.1	4.9	5.0	6.3
Fe (mg/kg)	39.47	28.69	39.49	48.35
Mn (mg/kg)	6.16	7.73	18.33	13.02
Cu (mg/kg)	2.35	1.79	1.4	1.49
Zn (mg/kg)	4.67	5.57	5.09	5.14
B (mg/kg)	0.72	0.77	0.68	0.75

5.3.3 Availability of soil microbial population in paddy and sugarcane cultivated fields in Mandya district (Karnataka)

Higher population of bacteria and Pseudomonas sp. were observed in samples from conventional farming paddy and sugarcane fields of Mandya district, Karnataka than samples from natural farming fields. No clear halo around the colonies was observed at 10^{-4} and 10^{-5} dilutions in natural farming fields of sugarcane (Table 5.7).

Table 5.7 Soil microbial population in paddy and sugarcane cultivated fields in Mandya district (Karnataka) (Log_{10} CFU/g soil)

Particulars	Paddy (n=1)		Sugarcane (n=1)	
	NF	Non-NF	NF	Non-NF
Bacteria	7.18	7.70	6.70	7.30
Fungi	3.38	2.78	3.51	2.18
Free-living Nitrogen-fixing bacteria	5.20	4.93	5.26	5.16
Phosphorus solubilizing bacteria	4.70	4.70	-	4.70
***Pseudomonas* sp.**	5.30	4.48	5.69	5.82
Trichoderma sp.	2.65	1.70	2.60	2.70

5.4 Results of the analysis of samples from Maharashtra

Some of the important findings/ observations during the visit to the study area in Parbhani and Hingoli districts (Maharashtra) are as follows:

5.4.1 Background of the study area in Maharashtra

(i) Major crops of the study region were: pigeon pea, turmeric, sugarcane, soybean, sorghum, wheat, etc. In small areas vegetable crops (viz., tomato, ladies finger, brinjal, ridge gourd, bitter gourd, chilly, etc.) and fruit crops (banana, papaya, moosambi etc.) were also being grown.

(ii) Most of the area (80-90%) was irrigated by bore wells and open wells.

(iii) Chemical methods of weed control were almost nil.

(iv) 80-90% farmers were using the chemical method of disease and pest control.

(v) The soil type of the study area was deep black soil.

5.4.2 Comparison of adopted practices under NF and Non-NF

Conventional farming (Non-NF) is being practiced in the study area since many years. The average size of the natural farming (NF) fields varied from 0.5-1.0 acre. These small plots for natural farming were drawn out from the conventional farming fields about 2-3 years back. A broad comparison of some of the ongoing farming practices being adopted in natural farming and conventional farming are given in Table 5.8.

Table 5.8 Practices followed by the sample farmers in Maharashtra

Practices	Natural farming adopted practices	Conventional farming practices
Mulching in turmeric	No mulching in turmeric.	No-mulching in turmeric
Farmyard manure	Application of the farmyard manure	Application of the farmyard manure.
Chemical Fertilizer	Application of *jeevamritha* at every 30-40 days intervals. No use of chemical fertilizers.	Application of the chemical fertilizers.
Tillage practices	Tillage practices were same as Non-NF.	Tillage practices were same.
Weed control	Traditional method of weed control such as uprooting/manual weeding/weeding by animal drawn weeder.	Traditional method of weed control such as uprooting/ manual weeding/ weeding by animal drawn weeder. The chemical methods for weed control were almost negligible.
Pests and diseases control	50-60% farmers applied the *neemastra* (neem seed based formulation)	80-90% farmers were using the chemical methods of disease and pest control.

The findings/ observations on natural farming adopted practices in study area are as follows:

(i) Jeevamritha: Most of the natural farming adopting (NF) farmers (≈100%) was applying jeevamritha.

(ii) Beejamritha: 50-60% of NF farmers treated their crop seeds with beejamritha

(iii) Acchadana/Mulching (soil mulch, straw mulch and live mulch): No such practices adopted by NF farmers

(iv) Wapasa/irrigation: No such practices were being followed in field under NF.

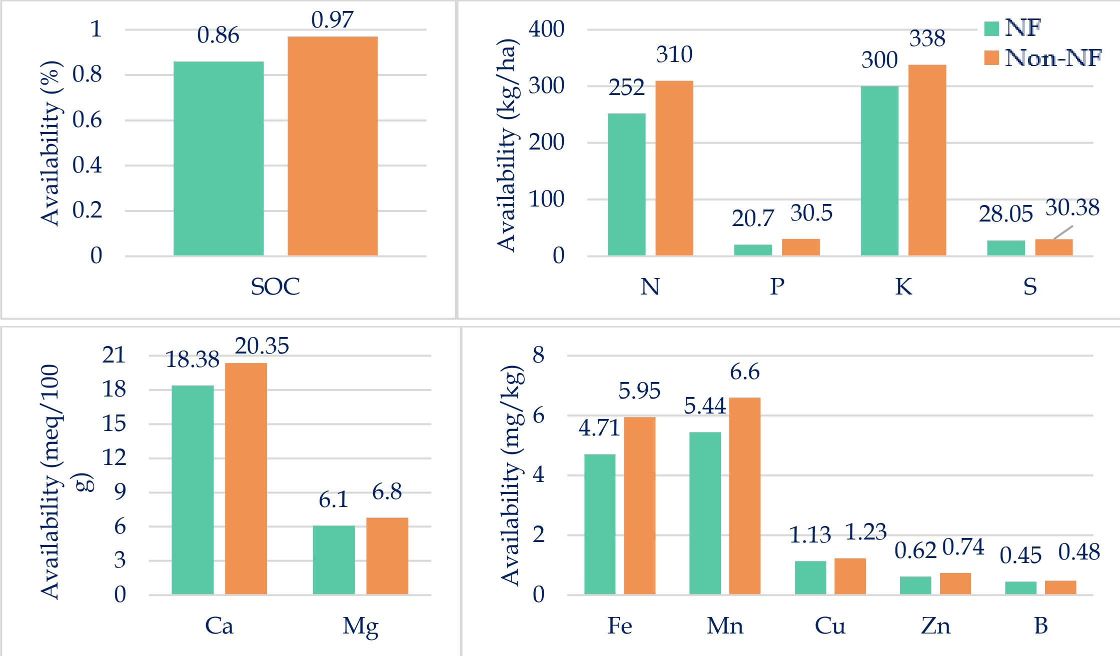
5.4.3 Farming practices adopted by sample farmers in Maharashtra

The details of the natural farming adopted practices and conventional farming practices in turmeric and sorghum cultivated fields in the Parbhani district and soybean and turmeric cultivated fields in Hingoli district are given in Annexure VIII(a-b). The soil samples were taken from sorghum and turmeric fields and analyzed for the available nutrients status in the soil under NF and CF practices.

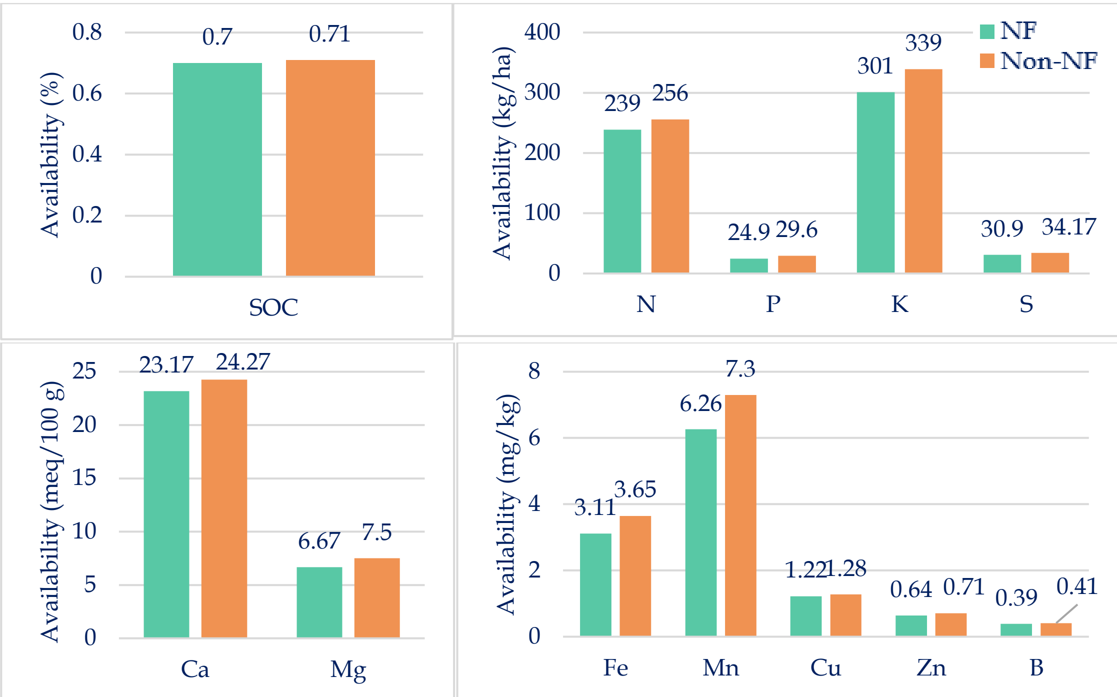
Sample collection in Maharashtra

5.4.3.1 Availability of soil organic carbon and soil nutrients status in turmeric and sorghum cultivated fields in Parbhani district (Maharashtra)

The average soil organic carbon (SOC) and soil nutrients in natural farming and conventional farming practices in turmeric and sorghum cultivated fields in Parbhani district (Maharashtra) are given in Fig 5.8. The data revealed that comparatively higher mean SOC was observed in conventional farming of turmeric as compared to the natural farming. Higher amount of mean available N, P, K, S exchangeable Ca and Mg, available Fe, Mn, Cu and Zn and B were found in conventional farming practices as compared to natural farming practices.



a. Turmeric (n=4)



b. Sorghum (n=3)

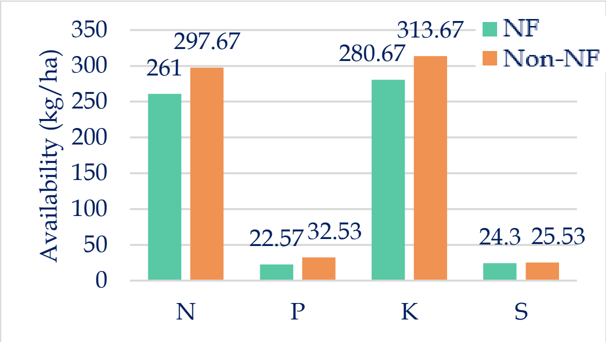
Fig 5.8 Availability of soil organic carbon (SOC) and soil nutrients in turmeric and sorghum cultivated fields in Parbhani district

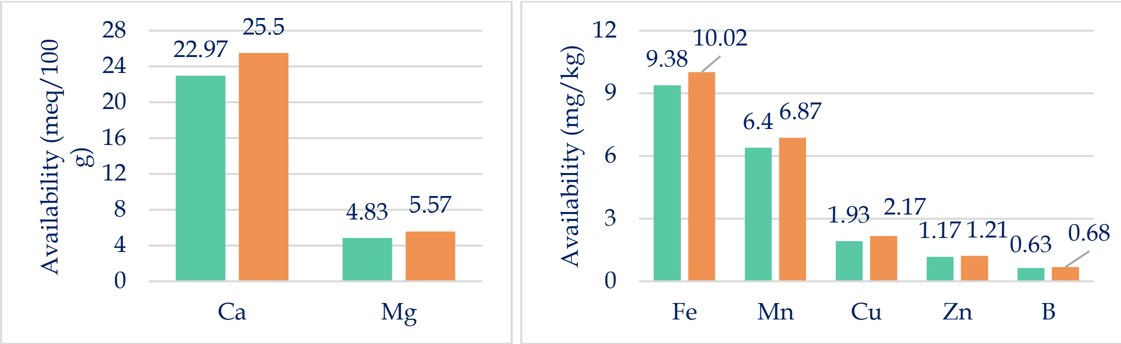
Similarly, in sorghum cultivated soils, higher amount of mean SOC, available N, P, K, S, exchangeable Ca, Mg, Fe, Mn, Cu, Zn and B were found in conventional farming practices as compared to natural farming practices. Overall, SOC was more in turmeric cultivated soils compared to sorghum cultivated soils due to higher biomass produced by the turmeric crop and higher leaf litter irrespective of the farming practices. Differences in terms of soil fertility with respect to major nutrients (NPK) in NF and Non-NF were more compared to secondary and micronutrients where soils of Non-NF fields had consistently higher available NPK. In case of micronutrients, these differences were very narrow. The plot-wise detailed results are given in annexure IX(a-c).

5.4.3.2 Availability of soil organic carbon and soil nutrients status in soybean and turmeric cultivated fields in Hingoli district (Maharashtra)

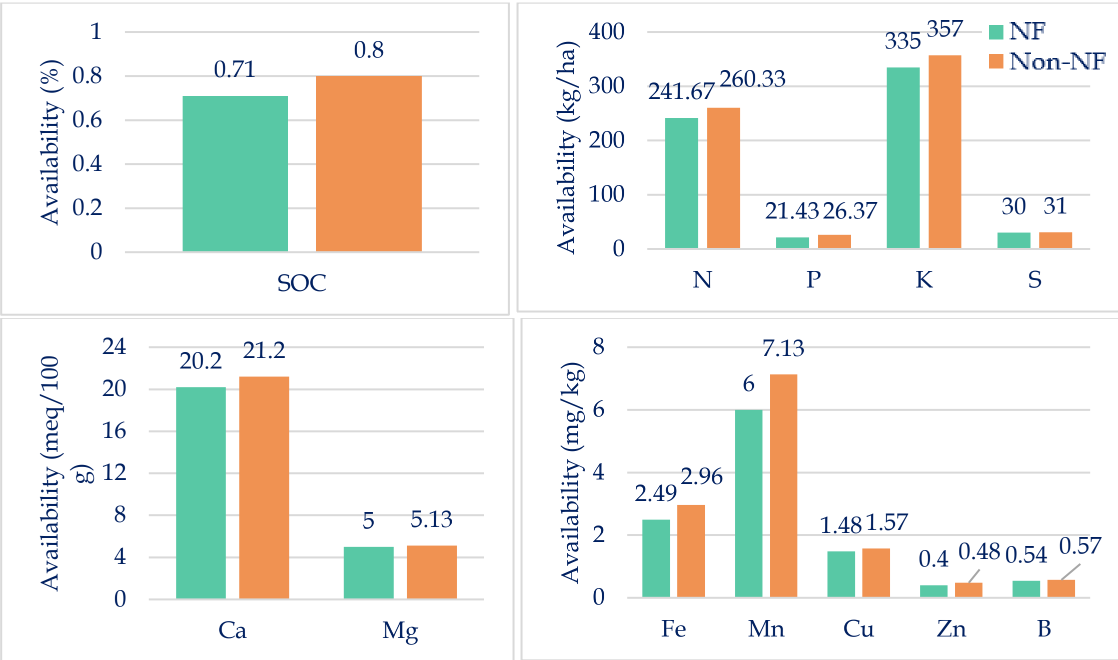
The data pertaining to the soil organic carbon (SOC) and soil nutrients in natural farming and conventional farming practices in soybean and turmeric cultivated fields in Hingoli district (Maharashtra) are given Fig 5.9. The data revealed that comparatively higher mean SOC was observed in conventional farming of soybean as compared to natural farming. Higher amount of mean available N, P, K, S exchangeable Ca and Mg, available Fe, Mn, Cu and Zn and B were found in conventional farming practices as compared to natural farming practices.

Similarly, in turmeric cultivated soils, higher amount of mean SOC, available N, P, K, S, exchangeable Ca, Mg, Fe, Mn, Cu, Zn and B were found in conventional farming practices as compared to natural farming practices. Overall, SOC was more in turmeric cultivated soils compared to soybean cultivated soils due to higher biomass produced by the turmeric crop and higher leaf litter irrespective of the farming practices. Differences in terms of soil fertility with respect to major nutrients (NPK) in NF and Non-NF were more compared to secondary and micronutrients where soils of Non-NF fields had consistently higher available NPK. In case of micronutrients, these differences were very narrow. The plot-wise detailed results are given in annexure IX(d-f).





a. Turmeric (n=2)



b. Soybean (n=3)

Fig 5.9 Availability of soil organic carbon (SOC) and soil nutrients in turmeric and soybean cultivated fields in Hingoli district

5.4.3.3 Soil microbial population in the soil samples collected from Parbhani and Hingoli districts of Maharashtra

The culturable microbial population of soil samples collected from 4 turmeric field and 3 sorghum fields each under natural (NF) and conventional farming (CF) in Parbhani district was enumerated. Similarly, in Hingoli district, soil samples were collected from 2 turmeric and 3 sorghum fields each under NF and CF. The samples from conventional farming turmeric as well as sorghum fields in Parbhani district recorded higher mean population of bacteria, fungi, actinomycetes, free-living nitrogen-fixing bacteria, phosphorus solubilizing bacteria (PSB), and Pseudomonas sp. as compared to samples from natural farming fields (Table 5.9).

Table 5.9 Average soil microbial population in turmeric and sorghum cultivated fields of Parbhani district, Maharashtra (Log_{10} CFU/g soil)

Particulars	Farming Type	Turmeric (n=4)			Sorghum (n=3)		
		Range	Mean	S.D.	Range	Mean	S.D.
Bacteria	NF	8.18-9.00	8.59	0.36	8.00-8.48	8.29	0.21
	Non-NF	8.30-9.64	8.82	0.53	8.78-8.95	8.87	0.07
Fungi	NF	3.00-3.65	3.45	0.26	2.70-3.65	3.32	0.44
	Non-NF	3.48-4.31	3.9	0.31	3.88-4.34	4.09	0.19
Actinomycetes	NF	3.00-3.54	3.29	0.19	3.00-3.60	3.2	0.28
	Non-NF	3.18-3.85	3.52	0.25	3.18-3.65	3.41	0.19
Free-living Nitrogen-fixing bacteria	NF	4.18-5.23	4.76	0.38	4.18-5.23	4.76	0.38
	Non-NF	4.40-5.31	4.92	0.35	4.40-5.31	4.92	0.35
Phosphorus solubilizing bacteria	NF	3.00-3.93	3.51	0.34	3.00-3.93	3.51	0.34
	Non-NF	3.18-4.13	3.76	0.36	3.18-4.13	3.76	0.36
***Pseudomonas* sp.**	NF	5.00-6.06	5.67	0.41	5.00-6.06	5.67	0.41
	Non-NF	5.40-6.26	5.97	0.34	5.40-6.26	5.97	0.34

Table 5.10 Average soil microbial population in turmeric and soybean cultivating fields of Hingoli district, Maharashtra (Log_{10} CFU/g soil)

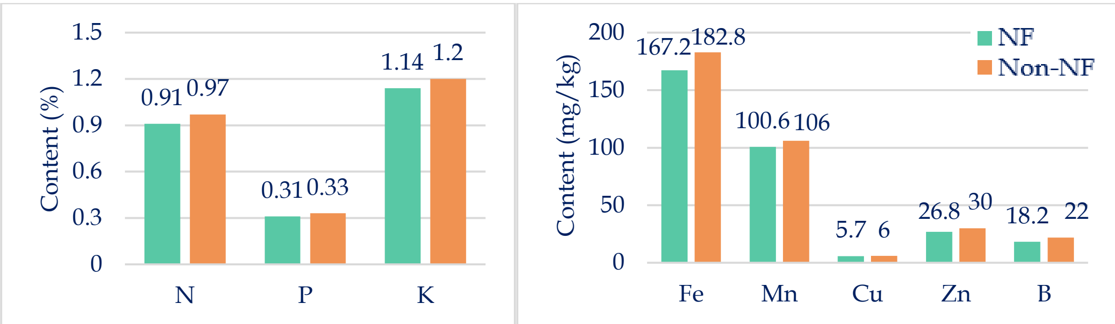
Particulars	Farming Type	Turmeric (n=2)			Soybean (n=3)		
		Range	Mean	S.D.	Range	Mean	S.D.
Bacteria	NF	4.18-4.85	4.47	0.28	7.70-8.40	8.03	0.29
	Non-NF	4.18-4.88	4.53	0.29	8.00-8.88	8.45	0.36
Fungi	NF	3.18-3.48	3.35	0.13	3.00-3.30	3.16	0.12
	Non-NF	3.40-3.78	3.63	0.16	3.30-3.40	3.37	0.05
Actinomycetes	NF	5.18-5.48	5.35	0.13	3.18-3.65	3.55	0.27
	Non-NF	5.30-5.90	5.62	0.25	3.54-4.15	3.86	0.25
Free living Nitrogen fixing bacteria	NF	4.40-4.60	4.50	0.10	8.18-8.48	8.33	0.15
	Non-NF	5.00-5.44	5.22	0.22	8.90-8.95	8.93	0.03
Phosphorus solubilizing bacteria	NF	2.70-3.81	3.26	0.56	3.00-3.65	3.33	0.33
	Non-NF	3.00-3.78	3.39	0.39	3.00-4.23	3.62	0.62
***Pseudomonas* sp.**	NF	5.90-6.23	6.07	0.16	3.18-3.48	3.33	0.15
	Non-NF	6.11-6.36	6.24	0.12	3.65-3.78	3.72	0.06

In Hingoli district also, samples from conventional farming soybean fields and turmeric fields recorded higher mean population of bacteria, fungi, actinomycetes, free-living nitrogen-fixing bacteria, phosphorus solubilizing bacteria (PSB), and Pseudomonas sp.

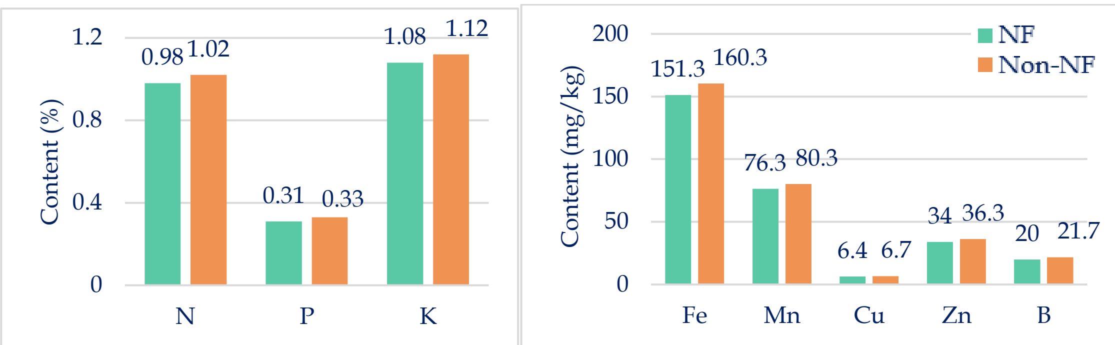
as compared to samples from natural farming fields (Table 5.10). Overall, it was observed that mean population of microorganisms were more in conventional farming as compared to the natural farming practices. The plot-wise detailed results are given in annexure IX(g-j).

5.4.3.4 Plant nutrient contents in the turmeric and sorghum plants in Maharashtra

The results pertaining to the plant nutrient contents of turmeric and sorghum crop are given in and Fig 5.10. The analysis of turmeric (above ground leaf) showed higher amount of mean N, P, K, Fe, Mn, Cu, Zn and B in the conventional farming practices as compared to the natural farming practices. Similarly, analysis of straw samples of matured sorghum plant showed higher amount of mean N, P, K, Fe, Mn, Zn and B in conventional farming practices as compared to the natural farming practices. The detailed plot-wise results are given in annexure IX(k-l).



a. Turmeric (n=5)



b. Sorghum (n=3)

Fig. 5.10 Average plant nutrient contents in turmeric and sorghum under NF and Non- NF conditions in Maharashtra

5.4.3.5 Nutrient & bacterial contents in *jeevamritha* samples collected from Maharashtra

Analysis of total nutrient contents of *jeevamritha* samples (about 2 weeks after preparation) collected from 3 farmers showed the presence of nutrients and bacteria. The mean values of the nutrients and bacteria along with range and standard deviation are given in Table 5.11. The detailed plot-wise results are given in annexure IX(m-n).

Table 5.11 Average nutrient content and bacterial counts in *jeevamritha* samples collected from Maharashtra

Particulars	Range	Mean	SD
OC (%)	0.19- 0.24	0.21	0.03
N (%)	0.04- 0.06	0.05	0.01
P (%)	0.018- 0.021	0.02	0
K (%)	0.04- 0.06	0.05	0.01
Ca (%)	0.04- 0.05	0.045	0.01
Mg (%)	0.01- 0.03	0.023	0.01
S (%)	0.014- 0.018	0.016	0
Fe (mg l^{-1})	38.9- 44.1	40.73	2.92
Zn (mg l^{-1})	1.30- 1.80	1.57	0.25
Mn (mg l^{-1})	1.12- 1.84	1.59	0.41
Cu (mg l^{-1})	1.90- 2.30	2.10	0.20
Bacteria (Log10 CFU ml^{-1})	8.18-8.40	8.29	0.09
n=3			

In case of Karnataka, we couldn't find minimum 3 fields from Natural Farming which were similar to Conventional Farming to compare the analysis. Therefore, soil samples and plant samples could not be analysed for Karnataka state.

5.5 Concluding observations from Lab Analysis

The following are the conclusions drawn from the results of the laboratory analysis of soil, plant and *jeevamritham* samples collected from the sample areas.

- In the study regions (Andhra Pradesh, Maharashtra and Karnataka), most of the farmers in their fields applied only some components of the natural farming viz., *jeevamritha* largely, and *beejamritha* and neemastra in a limited manner along with either farmyard manure (FYM) or compost. Similarly, most of the 'conventional farming' farmers also applied either FYM or compost, mulching, biofertilizers, etc. along with chemical fertilizers and thus followed the integrated nutrient management practices instead of doing purely chemical farming. The rate of application of organic inputs and their time intervals depended upon the farmers' economic status and availability of these organic inputs at local level under both the farming conditions. Therefore, true comparison between conventional and natural farming is difficult at farmers' fields.

- On an average, conventional farming (Non-NF) practices tended to show better results in terms of available nutrient status and soil organic C compared to natural farming (NF) fields. It could be due to the reason that Non-NF practices are being practiced for last many years in the study area. Whereas NF practices have been adopted for last 3-4 years only. It was also observed that the populations of most of the groups of microorganisms were higher in Non-NF fields as compared to NF fields. Although, in some cases, level of some micro-nutrients as well as microorganism counts were higher in case of natural farming fields.
- Analysis of plant samples showed higher nutrient content/concentration in plant samples with Non-NF crops as compared to that in NF crops.
- Study also revealed that the *Jeevamritha* samples contained large microbial population. As expected, total nutrients content in *Jeevamritha* solution was quite low.
- Many factors such as soil types, crops, farming practices, cropping pattern, history of soil/crop management by farmers, etc. affect the soil properties and crop productivity. In many cases, the NF and Non-NF plots are not on the similar parcel of land. Since baseline information of the same fields (Under study) are not available, it is difficult to establish the causation for lower level of nutrients in natural farming fields.
- In the present study, NF and Non-NF treatments were not laid out by the research team. The NF and Non-NF plots were identified as told by the farmers and officials. Therefore, there is a need to further validate the effect of Natural Farming on availability of plant nutrients in the soil through systematic studies conducted over a longer period at experimental stations/farms.

6. Crop Yield and Economics of Natural Farming

Effect of Natural Farming on crop yield and farm income is the most debated topic in recent years. Though there are several studies conducted in the past, the results are mixed. For instance, Kumbar and Devakumar (2017) reported that the experiment conducted at UAS, Bengaluru during 2014-15 revealed that application of *jeevamritha* at 2000 litres/ha recorded significantly higher green pod yield of french bean, which also had better crude protein and shelf life as well. However, when supplemented with 6% *panchagavya*, then yield of french bean further improved. Shubha et al (2017) observed higher soil microbial population and paddy yield at UAS, Bengaluru when Palekar's method was supplemented with *panchagavya*. Shyam et al. (2019) surveyed in 13 districts of Andhra Pradesh and found ZBNF to have partially improved soil health compared to lands of non-adopters as soil organic carbon (SOC) and total N in fields of adopters were higher (52% and 70%, respectively) than those in non-adopters fields, though available P and Zn declined under ZBNF practice.

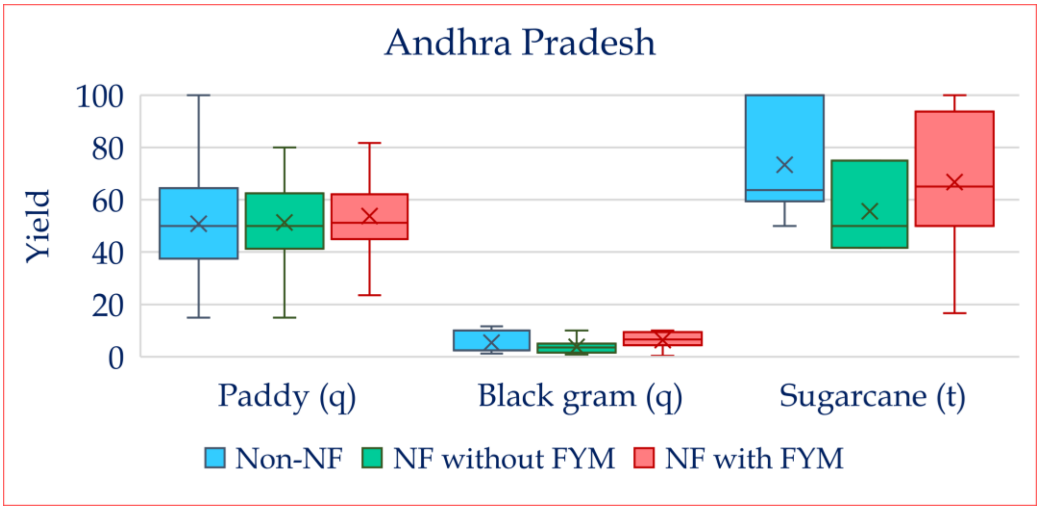
Though, 47 years long-term experiment conducted by Kumar et al (2018) suggests that the highest proportion of bacterial operational taxonomic units was recorded in balanced fertilizer (NPK) (without FYM) and therefore, this result suggested for the first time that continuous application of NPK encouraged the beneficial bacterial community without compromising of grain yield and straw biomass. The study further indicated that continuous application of NPK with or without FYM for more than four decades in paddy soil, encouraged certain bacterial community structure.

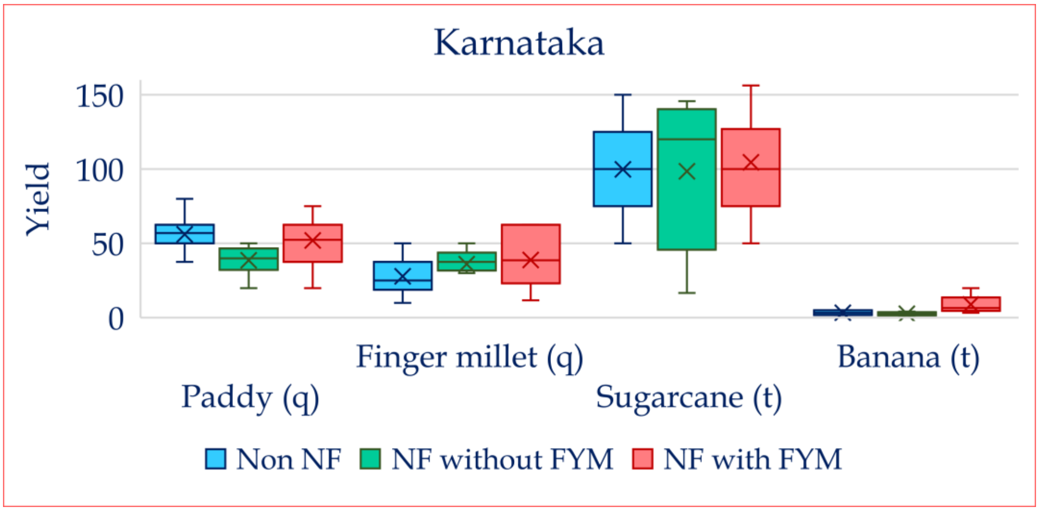
6.1 Crop Yield

Crop yield is the most important criteria currently being discussed under Natural Farming (NF). The yield of major crops in the three selected states have been worked out for three categories of farm crops- farmers using *Jeevamritha*, *Beejamritha*, etc. along with available Farm Yard Manure (NF with FYM), NF without FYM and conventional/ chemical farming (non-NF). The results are presented in the form of box plot (Fig. 6.1) and given in Annexure II. In most of the cases, the average yield (shown as 'x' in box-plot) for non-NF is higher when compared with those of NF without FYM. However, **NF with FYM has higher yield than both NF without FYM and non-NF farms in most of the crops**. For instance, in case of paddy in Andhra Pradesh, NF with FYM has marginally higher yield (53.79 q/ha) as compared to that of Non-NF (50.86 q/ha). Similarly, for black gram, non-NF harvested 5.4 q/ha while it is 6.4 q/ha for NF with FYM and 3.7 q/ha for NF without FYM. However, in case of sugarcane, the average yield is 73.33 tonnes/ha for non-NF whereas it is 66.81 tonnes/ha for NF farmers using FYM and 55.56 tonnes/ha for NF without FYM.

In Karnataka, NF with FYM has marginally higher yield for banana (8.89 t/ha), finger millet (38.92 q/ha) and sugarcane (104.55 t/ha). In case of paddy, non-NF has higher yield with 56.08 q/ha. In Maharashtra, turmeric yield under non-NF is higher at 40.03 q/ha than NF. NF with FYM is found to give higher yield in case of soybean (20.6 q/ha), jowar (10.51 q/ha), cotton (14.58 q/ha) and Chickpea (15.63 q/ha). It can be inferred from the above discussion that exclusively **Natural farming practices could not yield as much as conventional farming, however when Natural Farming practices was augmented with even smaller quantity of FYM, it invariably gave better crop yield than those from conventional/ chemical farming**.

To compare the yield of crops under non-natural farming (non-NF), natural farming (NF) with FYM and natural farming without FYM, one-way ANOVA has been used. In case of black gram in Andhra Pradesh, NF without FYM has significantly lower yield than NF with FYM (At p<.1). Also, in case of paddy in Karnataka, NF without FYM has significantly lower yield than non-NF as well as NF with FYM (At p < .05). The difference in yield could not established in other cases. The detail is presented in Annexure X.





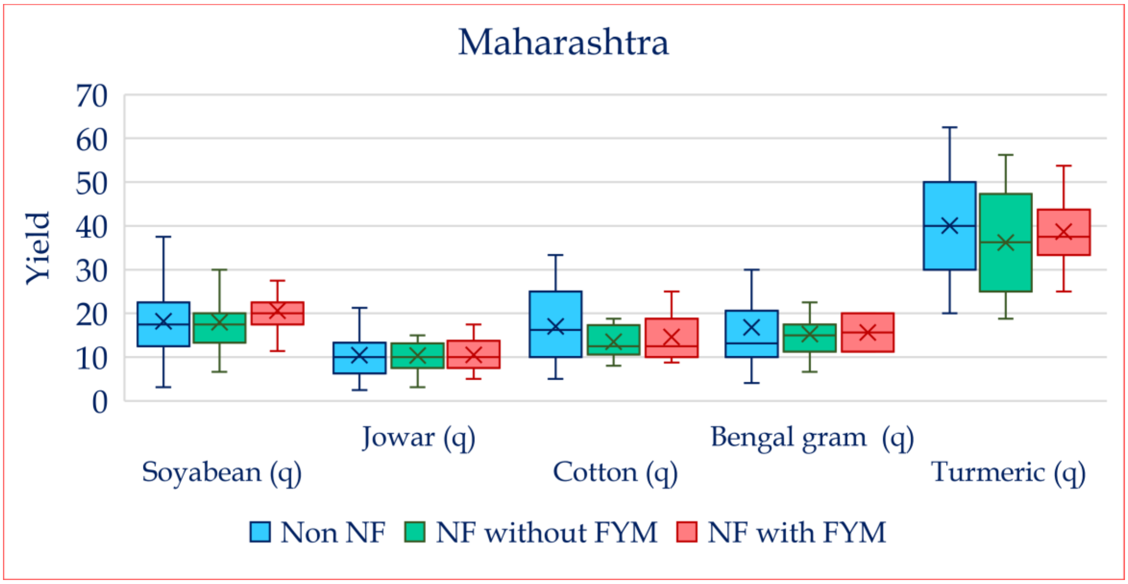


Fig. 6.1 Yield comparison among with- and Without- FYM users of NF farmers with non-NF farmers in study area

How to read a Box and Whisker Chart?

Box and whisker chart shows the variability of a data set using minimum value, maximum value and quartiles of the data set.

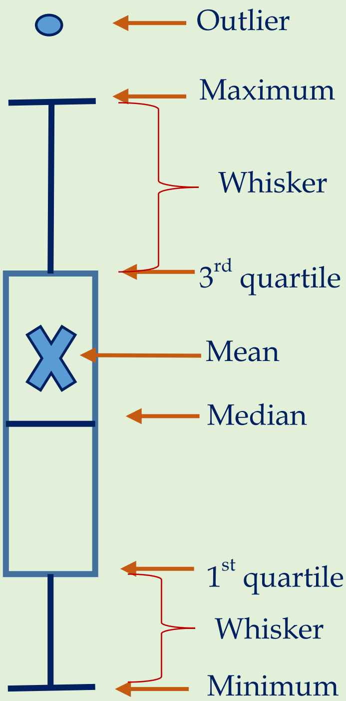
Interquartile range- The middle box represents the middle 50% data

3rd quartile- 75% data falls below the 3rd quartile

1st quartile- 25% data falls below the 1st quartile.

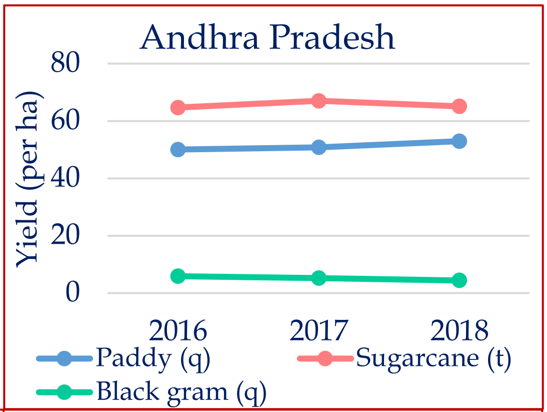
Outlier- Outliers are plotted as individual point. These differ significantly from other data

Whisker- These represent variability outside the 1st and 3rd quartile



6.2 Crop yield trend with Natural Farming

During field survey, we also asked the NF farmers about crop yield during past 3 years. It was done to ascertain whether yield of major crops under NF in the past is improving or otherwise. In all 3 states, it was found that the yield is more or less stable over the past three years for almost all the crops. (Fig. 6.2).



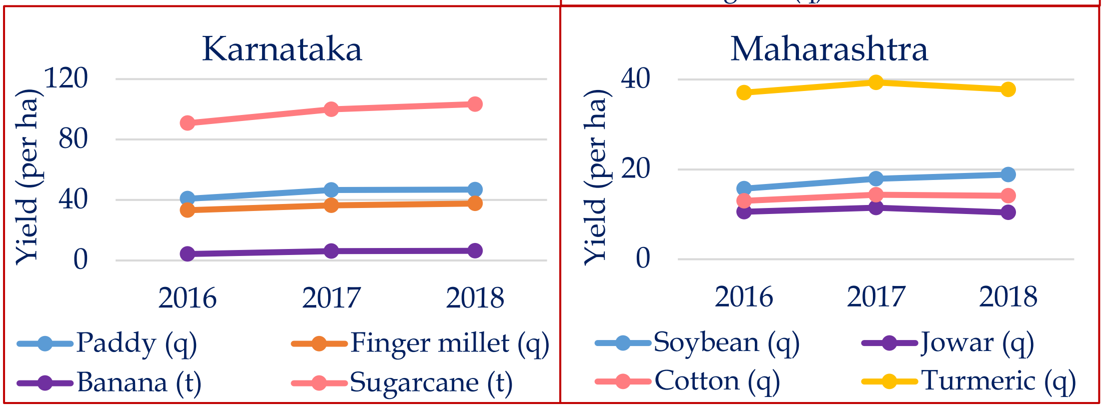


Fig. 6.2 Trend in yield of major crops under NF in last 3 years

6.3 Benefit-cost analysis of Natural Farming

The study examined use of various inputs in cultivation of major crops and estimated the paid-out cost and return for NF and non-NF farms. Table 6.1 details various costs incurred in cultivation of major crops in the selected states. The percentage of corresponding cost with respect to non-NF crops is also presented alongside. Material cost includes costs incurred in seed, *jeevamritha*, *beejamritha*, FYM, pest controlling solution for NF farmers, whereas for non-NF farmers, it is mainly seed, fertilizer, FYM and pesticide. Operational cost includes cost on land preparation, labour including harvesting. These two are added to arrive at total paid-out cost in both the cases.

In Andhra Pradesh, the material cost used by NF farmers in case of paddy and sugarcane is about 85 and 96%, respectively as those for non-NF farmers. Though, it is less than that of non-NF, it is higher than NF farms in other states. It may be because large number of farmers are applying purchased FYM and *ghanajeevamritha* in their field, as only 40 per cent of NF-farmers have indigenous cows and they depend on purchased materials. The operational cost in case of the same crops is closer to the non-NF counterparts. Hence, the total variable cost is lowered by only 5% in paddy and 8% in sugarcane. In case of black gram, the NF farmers could be able to reduce the total variable cost by around 55%. This could be due to reduction in material cost as only 23% farmers are applying FYM as compared to paddy and sugarcane in which 65% and 85% farmers are applying FYM (Fig. 6.1). Farmers are able to get marginally higher price for NF produce than non-NF produce. Except sugarcane, the B:C ratio is found to be improved in Andhra Pradesh for NF-farmers.

In Karnataka, NF-farmers have mostly home-made *Jeevamritha* and *Beejamritha* which has resulted into drastic reduction in material cost to around 24% in paddy, 45% in sugarcane and 26% in finger millet. The operational cost is little less than their non-NF counterparts. Farmers, here could be able to get maximum 150% more price as in case of paddy and minimum 50% more as in case on finger millet. It should be noted that NF farmers are cultivating mostly *Rajamudi*, *Rathnachudi*, and *Bangara Sanna* which have high market price. Here, the B:C ratio has increase by 3-4 times than that of non-NF.

In Maharashtra, there is a decrease in variable cost for all the major crops which is reduced by around 13% in soybean to 24% in cotton, turmeric and Chick pea. There is marginal increase in market price for all the crops as farmers are not getting niche market for sale of the NF produce. The B:C ratio is also improved by more than 15% in all the crops.

Table 6.1 Benefit-Cost comparison for major crops in selected states

Andhra Pradesh						
Particulars	**Paddy**		**Sugarcane**		**Black gram**	
	NF	As % of Non-NF	NF	As % of Non-NF	NF	As % of Non-NF
No. of sample farmers	*118*	*59*	*35*	*6*	*22*	*6*
Material costs (₹/ha)	9,050	84.82	26,780	95.53	856.62	39.10
Operational costs (₹/ha)	25,960	98.51	39,473	89.44	6,525	58.46
Total variables cost (₹/ha)	35,011	94.56	66,253	91.81	7,382	55.28
Yield (q/ha)	53	104.2	65	88.63	4.5	81.82
Market price (₹/q)	1,525	112	2,480	99.2	3,765	104.58
B:C ratio	2.3	123.4	2.43	95.79	2.29	154.44

Karnataka						
Particulars	**Paddy**		**Sugarcane**		**Finger millet**	
	NF	As % of Non-NF	NF	As % of Non-NF	NF	As % of Non-NF
No. of sample farmers	*42*	*22*	*18*	*14*	*15*	*23*
Material costs (₹/ha)	4,031	23.72	11,638	45.53	2,314	25.73
Operational costs (₹/ha)	17,491	91.66	28,914	92.36	17,688	97.48
Total variables cost (₹/ha)	21,522	59.66	40,552	71.31	20,002	73.71
Yield (q/ha)	47	83.65	103	103.48	38	134.9
Market price (₹/q)	3,945	264.51	5,200	198.7	3,700	153.14
B:C ratio	8.6	370.69	13.2	270.7	6.97	279.91

Maharashtra										
Particulars	**Soybean**		**Jowar**		**Cotton**		**Turmeric**		**Chickpea**	
	NF	As % of Non-NF	NF	As % of Non-NF	NF	As % of Non-NF	NF	As % of Non-NF	NF	As % of Non-NF
No. of sample farmers	*61*	*46*	*69*	*33*	*37*	*34*	*57*	*21*	*52*	*23*
Material costs (₹/ha)	6,838	65.6	3,869	55.4	6,595	37.8	45,121	68.5	4905	69.6
Operational costs (₹/ha)	12,851	105	9,593	102.8	19,934	115	28,468	92	8241	81.2
Total variables cost (₹/ha)	19,689	86.9	13,462	82.5	26,529	76.2	73,589	76	13146	76.4
Yield (q/ha)	19	103.6	10.5	100.8	15	88.3	38	93.8	15	84.9
Market price (₹/q)	3,208	103.7	3,091	115.1	5,021	101.2	5,957	92.8	4576	109.8
B:C ratio	3.13	123.7	2.42	140.67	2.84	117.24	3.04	114.72	4.3	122.15

7. Farmers' Perception towards Natural Farming

It is quite evident from the study that in selected states, the source of information about NF practices varied widely. In Andhra Pradesh, about 69 percent of farmers got training support from agriculture department. It may be noted that the state government of Andhra Pradesh were promoting Community Managed Sustainable Agriculture (CMSA) since last 15 years. In recent years, these farmers across all the districts were sensitized for ZBNF/ NF. In Karnataka state, mostly fellow farmers and NGOs shared the information (Fig 7.1). In Maharashtra, it is agricultural university, which are disseminating the information. The Agricultural Information Technology Centre (ATIC) provides common platform and facilitates the dissemination of all types of information among the farmers who utilizes it for propagating information on NF. Interestingly, most of the selected farmers attended training programme on Natural farming in the last 2-3 years (Fig. 7.2).

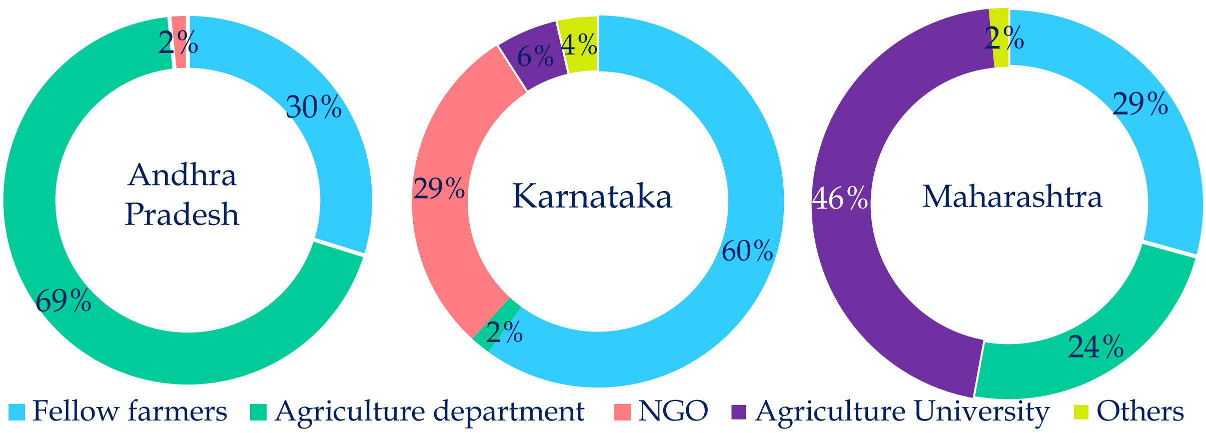


Fig. 7.1 Source of information on Natural Farming

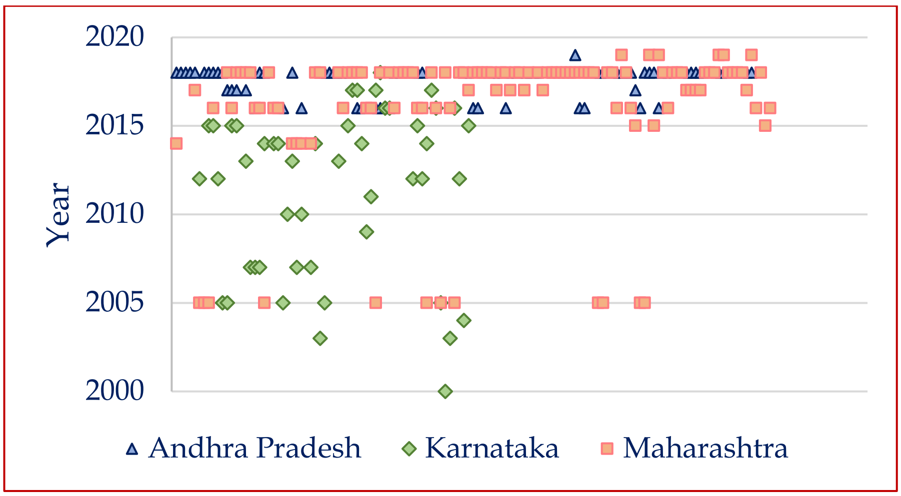


Fig. 7.2 Training attended by NF farmers (Year wise)

7.1 Benefits perceived by NF farmers

Farmers perceive many benefits of NF. In Andhra Pradesh, 81% farmers believe that the yield has increased (Table 7.1). In Karnataka, 56% farmers felt lower yield in NF. NF practice reduces the cost of cultivation which is felt by 86% farmers in Andhra Pradesh and more than 90% in Karnataka and Maharashtra. As far as produce quality and taste are concerned, around 90% in all the selected states found that NF produce has better quality than non-NF produce. In Andhra Pradesh, farmers are not getting any designated market for sale of NF produce, hence the produce in sold in the same market at almost same price. In Karnataka and Maharashtra, farmers are getting designated market where produce fetches higher price.

Table 7.1 Benefits perceived by Natural Farming farmers

Perceived benefits	Percent farmers		
	Andhra Pradesh	Karnataka	Maharashtra
Crop yield			
High	81	22	60
Same	17	20	16
Lower	2	56	24
Cost of cultivation			
High	14	7	9
Low	86	93	91
Produce quality			
Better	96	89	91
Same	3	11	9
Poor	1	0	0
Taste of produce			
Better	91	89	89
Same	9	11	11
Selling price			
High	22	96	81
Same	69	4	19
Lower	1	0	0
Sometimes high/low	8	0	0

7.2 Awareness among non-NF farmers

Though farmers perceive several benefits out of NF practice, more than 50% farmers among non-NF category in three selected states are not yet aware of NF. While only 2- 4% farmers discontinued and reverted to conventional system of farming owing to no obvious benefits of NF (Fig. 7.3). Lower crop yield and no immediate control over pests and diseases were found to be the reasons for discontinuation. Decreased landholding and no proper support from family members were also the reasons for discontinuation in few cases.

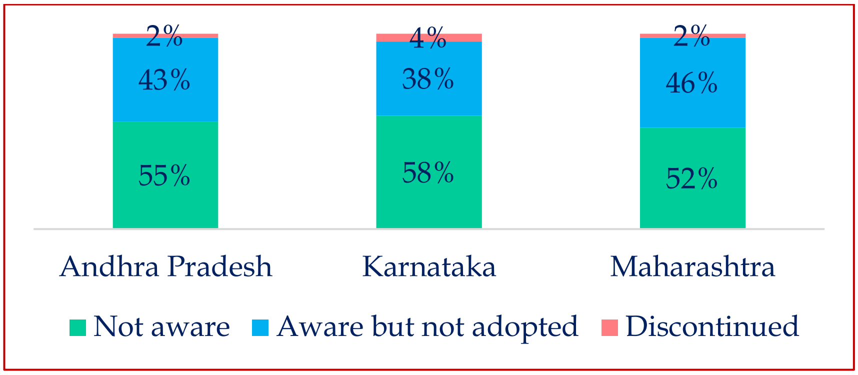


Fig. 7.3 Awareness about NF among non-NF farmers

7.3 Reasons for non-adoption among non-NF farmers

In Andhra Pradesh, non–availability of inputs due to very low percentage of ownership of indigenous cows was one of the major reasons for not adopting NF (Fig. 7.4). Though, 60% NF farmers also don't have indigenous cow, but they are buying all inputs from village's nutrient shops, while few are collecting from fellow farmers. Expectation of poor crop yield is also one of the reason for non-adoption of NF by non-adopted farmers (More than 30% in Karnataka and Maharashtra). NF is perceived to be more labour intensive and regular monitoring is required from the part of farmers. Preparation of *jeevamritha*, *beejamritha*, as well farm operations require regular attention by the farmer. It also discourages farmers for adopting NF. The farmers also expect higher price for the NF produce considering as free from chemical. Hence, non-availability of designated market for NF produce (As in case of Organic produce) drives reluctance towards NF adoption.

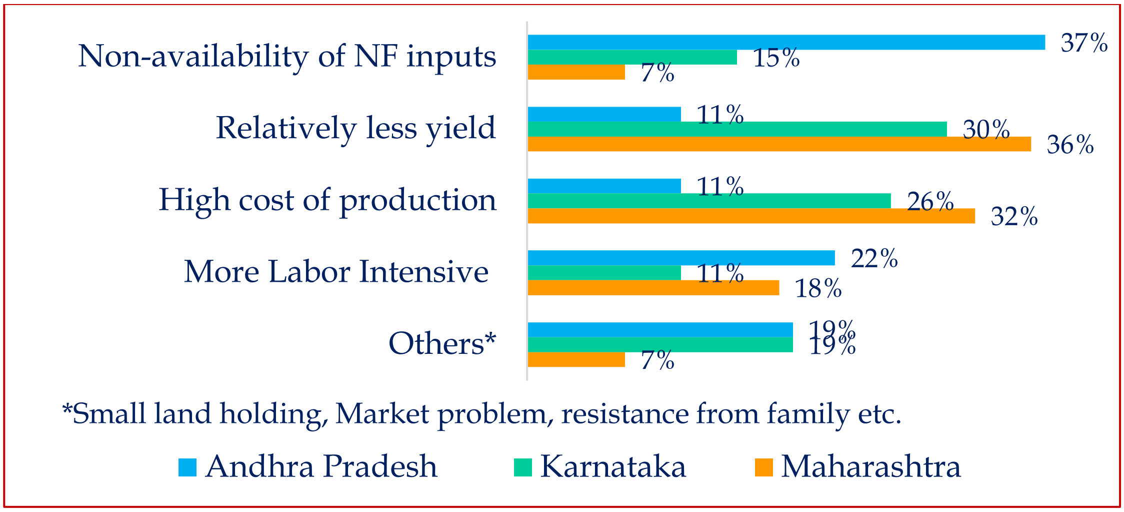


Fig. 7.4 Reasons for not adopting NF

Case – 1

NPM to ZBNF: a case from Vishakhapatnam, Andhra Pradesh

Shri Venkatasuri Apparao aged 48 years is practicing Natural Farming since past 5 years. He has an overall experience of 30 years in farming. Since 2009, he was practicing Non-Pesticidal Management (NPM) in Agriculture which he learnt from one of his fellow farmer. When ZBNF was promoted by Government of Andhra Pradesh in 2015, he was attracted to it and started practicing it in his 2 acres of cultivated land. He has attended training programme on ZBNF in Guntur during 2015 given by Shri Subhash Palekar. He says that he has read few books on Natural Farming also out of interest. He also worked as Inter Cluster Resource Person (ICRP) which he left as he was not able to concentrate on his own field. Out of 2 acres of land, he cultivates sugarcane in 1 acre and paddy in 0.5 acre. He has 2-year old mango orchard in the remaining 0.5 acre which is intercropped with brinjal and okra. The paddy is also followed by brinjal and okra in *Rabi*. In the last season, he harvested around 35 tonnes of sugarcane which he sold to sugar factory at ₹ 2500 per tonne.

He says that he is getting price same as that of chemical farming and feels that there is a need for special market for Natural Farming produces. Paddy yields 10 quintals which is being used for own consumption, whereas brinjal and okra which are sold in nearby market are helping in getting regular income. He is producing around 200kg of okra and 300kg of brinjal which is sold at an average price of ₹ 30 per kg. He is using seeds of his own produce even for brinjal and okra. The sugarcane trash is used for mulching in sugarcane and the paddy straw is used for livestock. He has one indigenous cow and one jersey cow. The indigenous cow is sufficient for practicing Natural Farming in his land and jersey cow is reared for dairy. He applies *ghanajeevamritha* during land preparation and *jeevamritha* once in a month, which he applies through flooding with the irrigation water. The vegetable crops are fed *jeevamritha* at plant bases once in a month. He is using *neemastra* to control pests and diseases as and when they appear. He is earning a net income of around ₹ 45,000 after incurring expenses which majorly includes labour charges. He feels that the appearance of the vegetables is inferior when compared to the chemical farming produce.

Farmer's name: V. Venkatasuri Appa Rao

Village: Dibbapalem, District: Vishakhapatnam, Andhra Pradesh

Case – 2

Natural Farming for quality fruits: a case from Vizianagaram, Andhra Pradesh

Shri Singampalli Satyam (60) has an experience of 40 years in farming. He started practicing Natural Farming 5 years ago. He says that inferior quality and taste of the produce from chemical farming made him to shift to Natural Farming. He has keen interest in learning new farming methods and wants to reduce use of chemical pesticides. He learnt Natural Farming method from the officials of State Agricultural Department. He has 5 acres of land and cultivates paddy in 2 acres, mangoes in 2 acres and cashew in 1 acre. The paddy is followed by black gram in 1.5 acres and green gram in 0.5 acres during rabi season. He has one jersey cow for milk purpose. He takes cow dung and cow urine from his fellow-farmers who have indigenous cows. Two of his family members also help him in farming activities. He obtains around 40 quintals of paddy from 2 acres of which 24 quintals is sold and the remaining is kept for own consumption. He gets around 4 quintals of black gram and green gram. Mango and cashew orchards are 25 years old and are yielding about 600 and 300 kgs, respectively. He applies *ghanajeevamritha* during land preparation and *jeevamritha* to the standing crop regularly. The orchard trees are given *jeevamritha* at an interval of 15 days. Weeding is done manually engaging labours. He obtains seed material for paddy from State Agriculture Department, whereas he uses own grown seeds for black gram and green gram. Last year, he earned a net income of around ₹ 80,000 out of which ₹ 26,400 is from selling paddy. Mr. Satyam is satisfied with the taste and quality of the produce and he says that the yield is better even if the rainfall is low. The fruits also do not require artificial ripening. He says that other farmers are also being attracted gradually to Natural Farming.

Farmer's name: Singampalli Satyam

Village: Gurla, District: Vizianagaram, Andhra Pradesh

Case – 3

Earning Regular Income through Mixed farming under Natural Farming: a case from Mandya, Karnataka

Shri Venkatesh, aged 44 years, is practicing Natural Farming since past 13 years. He owns one acre of land and has leased another one acre since 2013 paying ₹12,000 per year. When asked about the motivation for taking up Natural Farming, he said that his health took a toll few years back and was advised by the doctor to reduce intake of inorganic food. He learnt about Natural Farming from *Bharatiya Kisan Sangha*, an NGO. In 2005, he attended a 5-day workshop conducted by Shri Subhash Palekar in Arsikere, Hassan district. Since then, he has attended many workshops. He has two cows (Hallikar breed) along with 2 goats and 6 chicks. He is cultivating paddy (Rajamudi cultivar) as a solo crop in 1 acre of land, in two seasons. In the third season, he usually cultivates cowpea/ black gram/ sesamum. In other one-acre land, he is cultivating sugarcane at 12 x 2 feet spacing with vegetables crops as intercrops and banana as a border crop. These intercrops are helping him to obtain regular income. Earlier, he cultivated sugarcane at 8'x2' spacing which he changed to 12'x2' to accommodate more intercrops.

He uses *beejamritha* for seed treatment and applies *jeevamritha* once in every month through irrigation, which he is practicing since the beginning. Occasionally, he uses *neemastra* to control pest and diseases when the need arises. Though his wife supports him in some labour works, he hires labours for activities like weeding and harvesting. He sells the produce weekly at local markets branding them as Natural Farming produce and to several housing associations along with fellow farmers through *Bhoomithayi Belegarara Sangha*. He is also very active on social media platforms which he intelligently uses to find market for his produce. During last *kharif*, he obtained 14 quintals of paddy from his one-acre land which he sold to customers directly at a premium price of ₹4,000 per quintal. He obtained net profit of ₹60,000 from paddy alone. In the other one acre of land, he cultivated sugarcane and obtained 40 tons of produce. He sold it at ₹4,200 per ton and obtained a net profit of ₹1,20,000. He recalls that the expenditure is around ₹25,000 for cultivating 1 acre of sugarcane. He opines that, though the yield is less compared to chemical farming, it is increasing gradually. However, the quality as well as taste of the produce is high fetching better price at the market. His only concern is that Natural Farming is more labour intensive.

Farmer's name: Venkatesh

Village: T. Malligere, District: Mandya, Karnataka

Case – 4

Drawing inspirations from Fukuoka: a case from Tumkur, Karnataka

Shri Mahesh, aged 49 years, is an experienced farmer practicing Natural Farming before it became popular. After completing his diploma, he took up farming as a means of livelihood in his 11 acres of land. He was inspired from Fukuoka's Natural Farming method and practiced only mulching and zero tillage operations in his field. Later in 2005, he became aware of Subhash Palekar's Natural Farming method which was promoted by *Karnataka Rajya Raitha Sangha*. Out of his 11 acres of land, he has 100 coconut and 400 arecanut trees of 30 years age in 3.5 acres. In the remaining field, he has planted some perennial tree crops like jackfruit, guava, mango, custard apple and lime. He intercrops them with banana, papaya, finger millet, legumes and green leafy vegetables. He has 3 bore wells and a farm pond as source of irrigation. He also installed drip irrigation system and supplies *jeevamritha* through trench. He uses coconut and arecanut fronds, coconut husk for mulching around the base of the tree trunks to conserve moisture.

In a year, he obtains around 18,000 coconuts and sells them as copra at ₹15,000 per quintal (q) in Tiptur APMC. Around one thousand coconuts give 1.5 q of copra. He obtains 10-12 q of arecanut and sells at ₹35,000/q in APMC. Banana, papaya and other crop produce are sold to regular customers who visit his farm for purchasing. He has employed one permanent labour at ₹400 per day to look after all the farm activities. Besides, his mother and wife are also involved in farm activities. He uses only *neemastra* for controlling pests and diseases as and when they appear. As per his view, Subhash Palekar's Natural Farming method gives quick results compared to Fukuoka's Natural Farming. He has seen drastic increase in arecanut yield (from 5-6 quintals earlier to 10-12 quintals now). Same is his observation on coconut yield.

He has 2 Hallikar breed cows which give net profit of around ₹15,000 per year, besides having milk and ghee for own consumption. He also sells seedlings of lime, banana and guava. He has a facebook account in his name and a facebook page by the name '*Prakriti madilu*'. Besides farming, he conducts camps on his farm at nominal charges to create interest among city dwellers in Natural Farming. Till date, he has conducted >10 workshops and trained around 1000 farmers on Natural Farming.

Farmer's name: Mahesh

Village: Ammanaghatta, District: Tumkuru, Karnataka

Case – 5

Branding of Natural Farming Products: a case from Maharashtra

Shri Naresh Shinde, aged 48 years, is doing farming since last 18 years in his 17 acres of land. Debts due to huge operational expenditure and fluctuating prices of the produce, deterioration of health of permanent labour due to regular spray of chemical pesticides inspired him look for an alternative to chemical farming. Being an educated and progressive farmer, he used to attend meetings and interact with other farmers at different places. Subsequently, he learnt about ZBNF and got fascinated with it. Since 2014, along with his brother, he started practicing natural farming. Currently, he is having two indigenous cows, two buffaloes and two oxen. He is cultivating green gram, black gram and pigeon pea each in 2 acres of land, soybean in 6.5 acres of land, soybean + pigeon pea in 2 acres and turmeric+ chillies+ pigeon pea in 2.5 acres during kharif. In rabi, he cultivates chick pea in 4 acres, jowar in 3 acres, wheat in around 3.5 acres, and pigeon pea in about 6.5 acres.

He is using home grown seed and uses bullocks for land preparation and intercultural operations. He was spending around ₹ 2.0 lakhs for chemical fertilizers and pesticides earlier. Now, the farmer is spending only ₹ 50,000/- for preparing plant protection and nutrient solutions. He has borewell and applies *Jeevamritha* mainly through drip irrigation. For pest control, he prepares *Dashparnikashyam* solution and sprays in the field. Shri. Shinde, along with fellow farmers in the village, started an organic farming group called *Harithakranthi*. He also procures turmeric and pulses from other farmers. He prepares turmeric powder without boiling the turmeric fingers. The customers as well as other producers are connected through whatsapp groups. Recently, he is fetching a premium price by selling the produce to major cities like Pune, Mumbai and Hyderabad. He is selling natural farming products as organic products as there is no certification for natural farming products. The increasing health consciousness among the people is encouraging the farmers to promote natural farming among other farmers. He is also promoting natural farming in his village and surrounding villages by conducting the field demonstration.

Farmer's name: Naresh G. Shinde

Village: Sunpuri, District: Parbhani, Maharashtra

8. Scalability and Sustainability of Natural Farming

Natural Farming, as popularly known as Zero Budget Natural Farming (ZBNF[2]) is a set of alternative farming methods and considered to be a grassroot peasant movements, which has spread into many states in India in sporadic manner. Currently, it is being adopted in different forms by the farmers in most of the states in India, namely, Andhra Pradesh, Himachal Pradesh, Haryana, Karnataka, Kerala, Madhya Pradesh and Telangana. Though, the movement is considered to spread first time in Karnataka state in the year 2002, where members of *Karnataka Rajya Ryathu Sangha* (KRRS), a farmers' organization invited proponent of ZBNF, Mr. Subhash Palekar to address their members about ZBNF practices. KRRS is member of a global social movement called La Via Campesina (LVC). The LVC has adopted agroecology as one of its key tools to achieve food sovereignty and promotes diverse agroecology practices in Asia, Africa, Latin America and Europe (LVC, 2013).

Narayanamoorthy and Alli (2019) expressed that ZBNF has definitely helped preserve soil fertility, however its role in boosting crop productivity and farmers' income is not conclusive yet. On the other hand, according to Tripathi *et al*. (2018), ZBNF adopter famers in Andhra Pradesh had harvested 23 percent higher groundnut yield than their non-ZBNF counterparts; while adopter paddy farmers had marginal gains (6%) in yield. There are few literatures which support that the ZBNF practices has helped the adopter farmers in obtaining better crop yields, reducing cost of cultivation significantly and improving soil health of the farmers' fields. However, so far there are several articles published mainly in newspaper suspect about the claims of higher productivity and farm income with ZBNF practices. Though, there is no research report to prove these counterclaims as well. A study by Smith *et al.* (2020) suggests that ZBNF should initially be encouraged on only low-income farms to avoid yield penalties.

However, between these claims and counterclaims, significant number of farmers have adopted these practices, shunning the application of chemical fertilizers and pesticides, and adopting *Jeevamritha* prepared with cow dung, cow urines and other locally available materials. In most of the cases, farmers are using cow dung and cow urine of indigenous breed, in some cases, when indigenous cow is not available, they mix with dung and urines of bullock or buffaloes as well.

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[2] 'Zero budget' primarily means without using any credit, and without spending any money on purchased inputs. 'Natural farming' refers to a farming approach that emphasizes the importance of co-production of crops and animals, relying on easily available 'ingredients' to produce crop treatments on-farm, and microorganisms or mycorrhizae to build fertility of the soil. The practice requires most of the inputs for production (*Jeevamritha, Beejamritha*, concoction for pest control) as home-grown, farmers don't depend much on the market. Therefore, it has been named as ZBNF, might be on the pattern of Zero Tillage (ZT) farming, wherein minimum tillage, and not without tillage, is recommended.

8.1 Scalability of Natural Farming

Like any other agroecology, Natural Farming may also be considered as combination of three aspects- a scientific discipline, set of practices and a social movement. Scientific disciplines in the sense as it is being practiced by thousands of farmers in India since over 10 years. Different constituents of *Jeevamritha,* like cow dung is host of millions of beneficial microbes and when it is fed with pulses flour and jaggery, it multiplies very fast. Some of these help in fixing atmospheric nitrogen, solubilizing other available nutrients in the soil to the plants. Secondly, mulching and mixed cropping helps in improving soil carbon content, enriching the soil physical condition, further encouraging earthworms and other beneficial microbes to grow.

Table 8.1 Benefits expected from different components of Natural Farming

Components	Expected benefits
Jeevamritha**:** A fermented microbial culture derived from cow dung and urine, jaggery, pulse flour, and soil	Stimulate microbial activity to synthesize/ to make bio-available plant nutrients *in situ*; protect against pathogens; and promote earthworm activity
Beejamritha**:** a microbial coating for seeds, based on cow dung, urine, and lime	Protects young roots from fungus and seed borne or soil borne diseases
***Acchadana* mulching**: Covering the topsoil with cover crops and crop residues	Protects soil from direct exposure from sunlight, produces humus, conserves top-soil, increases water retention, encourages soil fauna, prevents weeds
Whapasa**:** Soil aeration, a result of *jeevamritha* and *acchadana*- represents water management through improved soil structure and humus content	Increase water availability, water use efficiency, increased activity of earthworm, increase resilience to drought
Inter-cropping/Mixed cropping: Cultivation of combination of different types of crops with different canopy and maturity time simultaneously	Reduces demand of particular types of plant nutrients and increases availability of different types of crop produce on regular basis to augment farmers income

Source: Adapted from APZBNF (2018).

Scaling often refers to the imposition of solutions that have worked well elsewhere. Changes can scale up and out, horizontally and vertically, through active processes or as an emergent property (Rosset and Altieri 2017). The nuances and pitfalls of scaling are of particular concern for agroecology because agroecological science and practice are rooted in knowledge developed by indigenous and peasant farmers in relation to specific territorial contexts (Brescia 2017; Rosset and Altieri 2017). Therefore, the vision of agroecological scaling reinforces autonomy, biocultural diversity, spirituality, and conviviality. It situates agroecology as one key element of broader societal transformations that challenge capitalism, colonialism, standardization, industrialization, patriarchy, and other forms of injustice (Ferguson et al., 2019). Thus, scaling up of ZBNF/NF practices requires serious constellation of policies, institutions, and corporations dedicated to creating and maintaining a healthy economic and policy environment, as has happened in case of Green Revolution technologies. Cacho et al. (2018) explains that agroecology is farmer-to-farmer movement. They proposed eight key drivers of the process of taking agroecology to scale: 1. Recognition of a crisis that motivates the search for alternatives, 2). Social organization, 3). Constructive learning processes, 4). Effective agroecological practice, 5). Mobilizing discourses. 6). external allies, 7) favourable markets, and 8) favourable policies. These factors are largely drawn from social movement theories like Frame theory, Resource mobilization theory, and the political opportunity framework (Parmentier 2014; Varghese and HansenKuhn 2013; Wijeratna 2018; Terán et al. 2018). In the long run, agroecology aims to reduce dependence upon external inputs, thereby contributing to the autonomy of food-producing families and communities (Rosset and Martínez-Torres 2012).

8.2 Factors to scale up ZBNF practices

There may be several factors influencing the large-scale expansion of adoption of ZBNF practices.

1. **Removing negativity around ZBNF/NF**: Currently, there are two very strong and diametrically opposite schools of thought co-existing in the society. The proponents of natural farming are spreading several misgivings to create disrepute to the agricultural scientific community and the institutions. They also attribute the large number of farmers' suicides and distress to green revolution technologies and associated scientific institutions. This has antagonizing effect on scientific community, who in turn, vehemently oppose the ZBNF practices saying it to be unscientific and unproven practices. In fact, the National Academy of Agricultural Sciences (NAAS), the Think Tank of agricultural sciences in India, made a representation to the Prime Minister Office (PMO) and requested to discontinue the support to ZBNF practices. In this confrontation, the main stakeholders viz. Indian farmers are confused about veracity of information of both the parties. Dialogues between two communities and evidence-based deliberation would add trust on the new practices. Currently, there are very few systematic research studies available to support or oppose the arguments. Under such circumstances, it is very important to create scientific evidences from the experimental fields to check the feasibility of the ZBNF practices in increasing the farmers' income through reducing cost of cultivation and/or increasing crop yield.

2. **Institutional arrangement for capacity building and awareness creation among the farmers**: The new practice suggested under ZBNF is big departure from the existing farming practices. Indian farmers, 85% of whom are smallholders, are also semi-literate. Therefore, they need constant flow of same information to adopt the new practices. It has been observed that several farmers are applying *Jeevamritha* as one more additional input. Currently, they are not believing completely about its efficacy. Once the scientific evidences are generated to support the claim, large scale capacity building programmes need to be organized at local level. All the *Krishi Vigyan Kendras* (KVKs) may be roped in to give training to a group of progressive farmers from each village, who in turn may influence other farmers by practicing themselves at their own fields.

3. **Farmers Producers Organizations (FPOs) formation and recognition as niche products**: Unless the scientific evidences are generated, it may be left to the farmers to adopt the ZBNF practices. However, FPO formation for ZBNF practices may be encouraged and the produce may be categorized as niche product. Since, no

Box 2.
Participatory Guarantee System (PGS) for Organic Certification

PGS India system is based on participatory approach, a shared vision, transparency and trust. PGS is a process in which people in similar situations assess, inspect and verify the production practices of each other and take decision on organic certification (PGS-Green and PGS-Organic). This process is facilitated by the PGS group itself or in some situations a supportive NGO/ Societies, Gram panchayaths, State/Central Govt. organization/agencies etc. Only the farmers which have completed full conversion period without any major or serious non-compliance be declared as "PGS-Organic". Farmers which have one or more major noncompliance or are under conversion period will be declared as "PGS-Green". If a farmer has satisfactorily completed the 3 main requirements of being certified (Attendance at group meeting and field-trainings, Farmer's Pledge and Peer Appraisal), they will most likely be certified. PGS is different from a Third Party system where the farmer has to convince the certifier of his/her "innocence" with huge amounts of paper "proof" as to his/ her organic integrity. In a small village, neighbouring farmers are empowered to make a final decision as to who is and isn't certified. A non-compliance by one farmer could influence the certification status of the group as a whole, so for that reason (among others) neighbouring farmers are more likely to: **a.** Deny certification to farmers known to be cheating, **b.** Proactively share knowledge, materials and moral support with a struggling farmer so they don't feel to resort to use of prohibited substances, **c.** Immediately apply reasonable sanctions to farmers for a non-compliance. The power of local social control is far greater than that wielded by trained Third Party inspectors who are outsiders and further visit only a few hours in a given year.

Source: PGS-India (2015)

chemicals are used in ZBNF practices, the cultivation may be brought under the ambit of Participatory Guarantee System (PGS) for certification as **PGS-Green**. It would help the adopter farmers in attracting premium price from the consumers.

4. **Establishing demonstration plot in each village panchayat:** Seeing is believing and learning-by-doing are one of the best strategies for peasant movement. Unless farmers see the successful model, it is hard to believe. Therefore, for success of ZBNF practices, at least one demonstration plot may be established either through local NGO or at progressive farmers' fields to demonstrate to the local farmers. Word-of-mouth and peer-to-peer communication would help the practice to reach to larger area in short span of time.
5. **Linking ZBNF farmers to Mid-Day Meal and Anganwadi Scheme:** To boost the morale of the ZBNF farmers, policy changes may be brought in the state to encourage procurement of chemical-free produce for Mid-Day Meal Scheme and Anganwadi Centres. This would create huge demand for variety of produces cultivated chemical-free.

8.3 Sustainability with ZBNF/NF

Performance of any farming practices may be examined in the light of four key sustainability metrics: productivity, economic viability, environmental impact and social wellbeing. Moreover, it is important to note that in the absence of any standardized practice recommended by any agricultural research institute or university, it is very difficult to consider the benchmark practice under ZBNF or Natural Farming. Environmental benefits of organic/natural farming include but not limited to elimination of chemicals use and reduced water pollution due to reduced pesticide residues, reduced nutrient pollution, better carbon sequestration, enhanced biodiversity (Greene, et al., 2009), improved soil condition, and more healthy food (O'Riordan and Cobb, 2001).

The proponent of ZBNF recommended use of *Jeevamritha* (for multiplication and triggering soil microorganisms) in certain formulations every month, mixed crops, mulching, *beejamritha* for seed treatment, local seeds. There is no need of adding anything extra, not even FYM. However, the farmers who are practicing Natural Farming deviate from these recommendations. The practices varied in terms of quantity of *Jeevamritha* used, some farmers applied farm yard manure (FYM), many farmers cultivate paddy, sugarcane, etc. as solo crop, etc. Therefore, for the study two categories of farmers were compared- First group, who don't apply any chemical fertilizers and/or pesticides, but uses *Jeevamritha*. They may be adding some more natural inputs like azolla in paddy, ghanjeevamritha, FYM or even not doing mixed farming. Second group, who are cultivating crops conventionally using chemical fertilizers and pesticides, any type of seeds, irrigation, etc.

Productivity: The present study conducted in 3 major states- Andhra Pradesh, Karnataka and Maharashtra has not been able to suggest any conclusive evidence about the superiority or inferiority of the Natural Farming over conventional farming in terms of crop yield (Fig. 5.1). The reason may be that the sample farmers practicing Natural Farming have no uniformity in adoption of different components. Invariably, crop yield in case of Natural Farming, when FYM is not added, has declined (1 to 10%) as compared to that in conventional farming (Annexure II). However, when application of Jeevamritha was supplemented with moderate quantity of FYM, the crop yield has improved significantly in most of the cases like blackgram and paddy in Andhra Pradesh, banana, finger millet and sugarcane in Karnataka, and soybean in Maharashtra. Smith *et al.* (2020) highlights the reduced production in high-input systems at national-scale due to ZBNF systems in the short term, while reiterating the possible yield benefits in specific conditions and over the longer term.

Economic viability: Since the NF alone failed to establish itself in improving the crop yield, it is important to look for other parameters. The profitability from farming can be ensured by three methods- improving crop yield, reducing the cost of cultivation and increasing the price of the product. Barring crop yield issue, inadvertently the Natural Farming has been successful in reducing the cost of cultivation. As far as price is concerned, progressive farmers are able to communicate to the potential customers to offer chemical-free crop produce at premium price. Thus, reduced cost of production and premium product price has helped the farmers in improving the farm income.

Environmental impact: Highlighting the importance of soil micro-organism, Rao (2007) opined that soil organisms act as primary driving agents of nutrient cycling, regulating the dynamics of soil organic matter, soil carbon sequestration and green-house gas emissions; modifying soil structure and water regimes; enhancing the amount of nutrient acquisition by vegetation; conferring stress tolerance, resisting pathogens and improving plant health. Though, Gunapala et al (1998) found that the ability of soil microorganisms to decompose added organic matter was the same in organic or conventional systems and that microbial diversity was not compromised by chemical farming. Shannon et al (2002) argued that organically managed soils maintain higher biodiversity and have been shown to have lesser incidence of soil borne diseases compared to conventional farming. Conventional agriculture has contaminated soils, water, and air; eroded soils and biological diversity; caused pest outbreaks; and in many cases, led to the indebtedness of farmers (Carroll, Vandermeer, and Rosset 1990; Lappé, Collins, and Rosset 1998). Widespread adoption of Green Revolution (GR) technologies led to a significant shift in the food supply function, contributing to a fall in real food prices. At the same time, it also spurred its share of unintended negative consequences, mainly, because of the policies that were used to promote rapid intensification of agricultural systems and increase food supplies. On one hand, GR-driven intensification saved new land from conversion to agriculture, the unintended consequences in water use, soil degradation, and chemical runoff have had serious environmental impacts beyond the areas cultivated (Pingali and Rosegrant, 1994; Pingali, 2012). Worldwide, improved seed–fertilizer technologies for wheat were less widely adopted in marginal environments and had less of an impact there than in favored environments (Byerlee and Morris, 1993).

Thus, ZBNF eliminates ecological risks related to land, organisms and water in its surroundings. By using homegrown fertilisers, fungicides or insecticides, the technique not only improves the ecology but also reduces production risks. it encourages the planting of intercropping across the spectrum- such as planting legumes, roots and tubers alongside commercial crops. It also improves nutrition absorption between plants, manages waste cycles, reduces the risk of pest incidence across seasons through various crops, and creates biodiversity on the farm. Finally, biodiversification critically reduces production and market risks for farmers. If in case there are pest incidences or failures of crops- the damage is mitigated by having multiple crops on a single farm: either a single pest will not hit all crops or trap cropping will attract enemy pests, thus cancelling out any outbreaks.

Social well-being: Improved farm income and diversified cropping system are the two important components which has been influenced by the Natural farming. Increased farm income has directly influenced the social being of the adopter-farmers. On the other hand, mixed cropping helped the farmer-growers in increasing diversity in the household food basket. Thus, except crop yield, the Natural Farming practice has established itself as sustainable agricultural production system and being continued by those adopter-farmers, despite more labour engagement and even yield penalty in some cases.

Moreover, Smith *et al*. (2020) concluded that the maximum potential nitrogen supply may likely be only 52-80 percent of the prevailing national average fertilizer application rate, which may put yield penalties in higher input systems. According to the study, under ZBNF practices recommended, maximum nitrogen may be supplied to the crops as 10% from *Jeevamritha* (liquid and solid together), 10% from mulching of dried biomass, 18% from nitrogen fixation by heterotrophic microbes, 24% from intercropping/legumes in rotation, and 18% from azolla. Thus, there is need of addition of manure to supplement 24% of nitrogen. The study suggests that although ZBNF has a substantial role to play in improving the productivity and viability of low-income farms, if it is strongly promoted to high-income farmers, an immediate decline in national food production is likely. The systematic research is needed to quantify sources of nitrogen, understand the impacts of ZBNF on soil organic matter and ensure that higher levels of nutrients continue to be available to crops, so that crop yields can be maintained over both the short and long term.

8.4 Challenges in ZBNF/NF adoption

In a such diverse country like India, one farming practice cannot suit to all kinds of soil types, agro-climatic conditions, and all crops. The country has 146 million farmers, out of which 100 million farmers have hardly 0.4 ha of operational holding. Their socio-economic backgrounds are different. Therefore, it would be utopian idea to assume that ZBNF/NF practice would be adopted by all the farmers in India, no matter how best this practice proved to be. Following may be the major challenges in spread of this practice at large scale:

1. Convincing the scientific community: Unless the scientific data and evidences are created by the research institutes, it would be difficult to convince different stakeholders to develop broad consensus for its adoption. In such situation, there will always be suspicion among the stakeholders and farmers about its efficacy. If large network of ICAR institutes/ agricultural universities and KVKs have different views, then farmers would be in big confusion about this. Therefore, all aspects of Natural farming, particularly importance of dung and urine of indigenous cows, growth and survival of different useful micro-organisms in *Jeevamritha* and after its application in soil, impact on soil microorganisms, earthworm activity, fungal and bacterial diseases, cycling of nutrients from deep in the soil fertility, response of different crop varieties under different cropping and agro-ecological systems, benefits due to reduced use of chemicals in agriculture- financially, environmentally, micro- and macro-level, etc.

2. Adoption by large-size farm holding: It has been observed that ZBNF practice requires regular monitoring of the field for monitoring of nutrient deficiency as well as pests & weed infestation. Further, preparation of huge quantity of *Jeevamritha* and its application at regular interval may require increase in labour demand, which may increase the cost of crop cultivation. Thus, the practice may be more applicable for smallholder farmers with 1-2 family labour available at home. Therefore, adoption by large farm-size holding would be a herculean task.

3. Doubtful in case of high-input monocropping region: The ZBNF practice is contemplated to be agroecological approach, in which crop/farm diversity is must. In case of monocropping, wherein huge quantity of similar types of nutrients are applied, this practice may not give better/same crop yield as compared to existing practices of application of HYV, chemical fertilizers & pesticides. Therefore, in the region like Indo-Gangetic Plains, where farmers cultivate single crop in whole field in a season may not be interested to adopt this. It may have repercussion on total foodgrain production for the country if adopted at large scale by most of the farmers.

4. Reduced scope of mechanization: The benefits of ZBNF can only be realized when farmers cultivate several crops together as inter-crop or mixed crops so that demand for specific nutrients don't lead to nutrient exhaustion in the soil. Inter-/mixed crops can also be harvested at different points of time. This creates big hindrance in large scale adoption of farm machinery for sowing, harvesting, even other management practices. Achieving economy of scale and farm efficiency may always be the challenge in such case.

5. Continuous improvement in crop yield: Crop harvest is the first stage of output realization by the farmers. Since the ZBNF practice forbids application of improved cultivars/ hybrid seeds, it would be difficult to keep the farmers motivated to grow the crops with this practice, as possibility of reaching yield plateau is quite imminent. Therefore, it requires experimenting with ZBNF/NF practices with different genotypes/ cultivars to get continuous improvement in yield.

6. Setting up institutions for recognizing ZBNF produce: It is obvious that ZBNF products are different than conventionally produced commodities. Unless some mechanism is developed to place this product as niche product in the market, it would be difficult to attract premium price for ZBNF products. Therefore, different institutional mechanism and policy change would be required for producing, aggregating, certifying and bringing near to the final consumers. It may be appropriate to encourage the farmers to go far this practice in collective way, so as to economize the whole process at scale.

9. Conclusions and Way Forward

Zero Budget Natural Farming (ZBNF)/Natural Farming (NF) is based on the principles of agroecology which is founded on cultural creativity, that encourages ecological biodiversity by improving community relations, deepening mutual aid, increasing people's control over their lives, and placing all tools under the control of producers. It is polar opposite to industrial agriculture that works on one-size-fits-all concept with sustainable intensification and monoculture in the centre overemphasizing on productivity, and competitiveness based on neoliberal economic and scientific precepts. Agroecology based agriculture got its legitimacy in the year 2014, when International Symposium on Agroecology for Food Security and Nutrition was organized in Rome by the Food and Agriculture Organization of the United Nations (FAO). This was followed by the International Forum for Agroecology, held at Nyéléni, Mali in 2015 organized by the International Planning Committee for Food Sovereignty (IPC) to push for food sovereignty. The social movements and civil society actors that are part of the IPC, including *La Vía Campesina* (LVC), the National Coordination of Peasants' Organizations of Mali (CNOP), the Latin American and Caribbean Agroecology Movement (MAELA), the Latin American Scientific Society for Agroecology (SOCLA) and others, went on record at Mali to oppose what they perceive as a move by mainstream institutions to co-opt and reduce agroecology to a set of eco-techniques in the toolkit of the industrialized food production model (Giraldo and Rosset, 2017).

ZBNF/NF is being promoted by the Government of India in a big way which is reflected by the recent initiatives and announcements. Some State Governments especially Andhra Pradesh, Karnataka, Maharashtra, Himachal Pradesh, Kerala and Madhya Pradesh have also joined the movement. The proponents proclaim that NF practice will eliminate the problems of dependence on costly inputs as well as health and environmental concerns particularly related to use of chemicals. On the other hand, the critics call the NF practice as unproven which cannot bring any tangible benefit to either farmer or to consumer. Keeping in view the above contrasting understanding and interpretation, the study has been carried out in three leading NF adopted states viz. Andhra Pradesh, Karnataka and Maharashtra by interviewing NF as well as non-NF farmers.

Natural Farming is found to be widespread in Andhra Pradesh with majority joining the bandwagon during the last 5 years, whereas in Karnataka and Maharashtra, adoption of NF though started more than 15 years back, is very much sporadic. There are farmers in Karnataka and Maharashtra who are practicing NF since more than 10 years and are still continuing. Though, there are certain practices prescribed in Natural Farming, most adopted practices are use of *Jeevamritha*, *Beejamritha* and other plant protection materials. Mulching and different irrigation technique (*Wapasa)* are not popular practice. There is always scope for tweaking and innovation in these practices like *Ghanajeevamritha* and use of Azolla in paddy field in A.P. Inter or mixed cropping, as advocated in NF is found to be followed by some of the farmers, except in paddy. Paddy is always gown as solo crop in the study area.

Owning an indigenous cow may not be a prerequisite, as the requirement of cow dung and urine is very low (10 Kg dung and 5-10 L urine) for preparation of *jeevamritha or beejamritha*. Additionally, it was clearly exhibited in Andhra Pradesh that farmers are buying/arranging these inputs from other farmers. There seems to be a viable rural micro-level business proposition in processing and marketing of NF inputs. It can also be done at community level.

The lab analysis of soil and plant samples could not draw a concrete conclusion on effect of NF on soil and plant properties. Various factors influence soil properties and soil health, such as soil type, soil pH, cropping pattern and fertilizer applications in the past, agro-climatic conditions, etc. The microbiological properties of NF and non-NF were also showing mixed results. This could be due to very small sample size along with different soil types of the collected sample. However, from farmers' point of view, the ZBNF has helped in improving their health (may be due to non-use of pesticides and availability of food diversity) and soil health (as earthworm population increased).

The crop yield in NF is not higher as compared to conventional farming. However, when supplemented with FYM/ *Ghanajeevamritha*, crop yield improved significantly. It was also evident that there is substantial reduction in input cost in NF as compared to non-NF due to non-use of expensive agro-chemicals. This is resulting into significant reduction in cost of cultivation of all the crops. This has resulted into better profitability (B:C ratio) for NF farmers. Thus, Natural Farming may not be looked as yield enhancing farming practices, but definitely increases farmers' income through cost reduction.

The benefits as perceived by NF farmers is manifold which ranges from less cost of cultivation, better quality and taste to premium price. Though the premium price benefit is not experienced by many farmers, it creates a new market opportunity for tapping a middle-class customer segment, who aspire to consume chemical-free produce, but are hesitant to pay exorbitant price for organic produce. These may be recognized as niche product so as to attract premium price in the market. It can be done with Participatory Guarantee System (PGS) certification as PGS-Green which will help the farmers to convince the consumers to pay premium price.

At the same time, essentiality of NF inputs viz. *jeevamritha*, *beejamritha* etc. along with regular engagement in farming discourages farmers for NF adoption. The apprehension about pests and diseases also prohibit most of the farmers in adopting this practice. Moreover, scientific evidences from the experimental field is the need of hour to explore the possibilities of NF in increasing the yield of different types of crops under different agro-climatic conditions under different agroecology.

9.1 Policy Recommendations

Natural Farming (NF) practices or Zero Budget Natural Farming (ZBNF) practices encompass much larger perspective than the scopes visualized in common parlance. The discussion/ debate on 'Zero Budget' may not be tenable, as the terminology might be more appealing to communicate to the rural farmers, and secondly, actual practices definitely lead to significant reduction in market dependency for farm inputs. As Soil Microbiologists emphasize upon the important roles played by the invisible micro-organisms in the healthy soil, the NF practice can be sustainable if it is adopted in true spirit. It is well documented that millions of fungi, bacteria, actinomycetes, etc. available in healthy soil make available all those nutrients which are needed for all types of plants through fixation, solublization and mineralization, provided the soil is covered with organic matter (mulch), and proper moisture is maintained. However, application of chemical fertilizers and/or biocides has serious damaging effect on these microorganisms, and therefore, plants depend mainly on the external nutrients applied to the soil. Moreover, from operations point of view, like preparing *Jeevamritha*, *Beejamritha*, multi-cropping, different *kasayams* for pest management, etc. NF require not only regular monitoring and engagement, but also the conviction to continue these practices. Even though, the NF practices results into better farm profitability, it would be a humungous task to implement these practices by relatively large farm land, as poly cropping may not be compatible with farm mechanization, particularly sowing and harvesting. It may be quite feasible for the smallholders, which has adequate family labour to look after the field and use these inputs on regular interval.

Having said that, following policy recommendations may be applicable for expansion and sustainability of Natural farming practices:

1. Systematic research should be conducted at ICAR institutes/SAUs: There are several issues related to Natural Farming, which require further refinement as well as to create credibility for the practices. Such as **i)**. effect of dung and urine from different species (buffaloes/ bullocks/ crossbred, or other ruminants, etc.) for preparation of *Jeevamritha* and *Beejamritha*, **ii)**. quantity and frequency of *jeevamritha* application, **iii)**. composition of jeevamritha, **iv)**. possibility of preparation of Jeevamritha concentrate for longer shelf-life and portability, **v)**. effect of Natural farming on different crop combination and under different agro-climatic and irrigation conditions, etc.

2. Impact of Natural farming may be multi-faceted: Comprehensive socio-economic study on impact of Natural Farming may be conducted to examine its implication on **i)**. carbon footprint due to saving of chemical fertilizers (manufacturing and distribution) and its effect on climate change; **ii)**. Saving of fertilizer subsidy; **iii)**. Improvement in soil health; **iv)**. Increased crop diversity and food diversity at farmers' household level; **v)**. improvement in farmers health- reduction in time and money spent for hospital visit; **vi)**. improvement in farm income, etc.

3. Creating awareness through training and demonstration by KVKs: Phase-wise roll-out of capacity building of farmers and demonstration may be initiated by the selected Krishi Vigyan Kendras (KVKs) in each agro-climatic zones and for different crops. The KVKs may also experiment on the efficacy of the practices with improved varieties/ hybrids.

4. Certification of Natural Farming produce: Since the natural farming produce is chemical-free, the consumers would be ready to pay premium price for the product. Therefore, proper mechanism may be developed for certification of these products under PGS, to create different segment in the market- between conventional products and organic products.

5. Encouraging Farmers Producers Organization (FPOs) based on Natural farming: Special incentives may be given to the FPOs promoting exclusively the Natural Farming practices. Such FPOs may be given financial support for developing monitoring system as well as value addition and marketing of NF produce.

Natural farming or ZBNF started as a grassroots movement, aiming to provide multiple benefits, both to the environment and to farmers. Promoters of ZBNF claim that the soil already contains all the nutrients needed for plant growth and that the action of microbial cultures added to the soil releases these nutrients from the soil itself. However, agricultural scientists argued that the practice would result in a sharp decline in crop production and make soils less resilient to droughts. From the study, it may be concluded that the Natural Farming practices may be feasible in the regions where scope of intercropping is quite prevalent or can be promoted, and smallholder farmers can manage their land with available family labours. In case of high input regions, where monocropping is widely adopted, the practice may not give desired results in terms of crop yield and profitability. The extent of indirect benefits and long-term sustainability of the system also need further research to validate the practice. However, if the natural farming produce is placed as niche product, it may offer an alternative choice for the farmers as well as consumers.

There are lots of noises around the nomenclature of 'Zero Budget Natural Farming' (ZBNF), particularly about 'Zero budget' and 'Natural'. More pertinent questions may be-

1) Whether the composition of *Jeevamritha* is capable of multiplying micro-organisms to such extent that it can suffice the bio-availability of all types of nutrients needed for different types of crops grown in the field?

2) Whether the nutrients reserves present in the soil would be maintained in future with continuous ZBNF/NF practices?

3) What are the differences in microbial composition in the dung and urine of indigenous cow and other animals like indigenous bullocks, cross-bred cattle or buffaloes, which may be used for *Jeevamritha* preparation?

4) Can ZBNF practices be economically profitable in case of monoculture/ solo crop?

5) What would be the performance of ZBNF practices in different soil types and under different agro-climatic conditions, and with improved seeds?

6) Can the ZBNF practices be standardized for different crop combinations?

Above and many other questions if any, can only be answered by conducting systematic research in lab and field experiments at research institutes. Moreover, ZBNF practices give an option of producing crops non-chemically and without applying huge quantity of FYM and to the middle-class consumers to have chemical-free food products at affordable price.

Frequently Asked Questions related to Zero Budget Natural Farming (ZBNF)/ Natural Farming (NF)

In this study, we have used ZBNF and NF as interchangeably, as 'Zero Budget' is symbolic representation about minimum expenditure to be incurred for purchase of farm inputs from the market. As in case of 'Zero Tillage', it is minimum tillage, rather than no tillage. Though, the basis of selecting ZBNF/NF farmers have been only two components of ZBNF, viz. application of *Jeevamritha* and no application of any kind of chemical fertilizer or pesticide, one may argue that they aren't exact ZBNF farmers. Further, entire study is based on the responses of the randomly selected farmers from both the categories- ZBNF-adopters and non-adopters. Thus, trust in truthfulness of the statement on recall basis has been assumed, as in the case of any social science survey.

While conducting this study, the research team confronted with several researchers, farmers and other stakeholders, who raised several questions regarding efficacy of ZBNF/NF. Following questions emerged during the discussion. The answers given here are mainly intuitive and based on survey and field visits.

Q1. Can ZBNF/NF practice replace the conventional/chemical fertilizer & pesticides-based farming in India?

A: No. It can't replace the conventional farming practices completely, which are based on intensive use of modern technologies, including improved cultivars/ hybrids, chemical fertilizers, chemical pesticides, herbicides, etc. Though, ZBNF/NF is one type of organic farming, however it may be considered as third option of farming, placed between conventional farming and organic farming. The ZBNF practices and the produce may be seen with different perspectives, and not as replacement of conventional farming. Under this practice, farmers produce crops without using any agro-chemicals unlike conventional farming, and at the same time, it does not require huge quantity of FYM, unlike organic farming. On the other hand, consumers can have option to purchase such food products, which are free from any chemical residues. Since the possibility of crop yield being low through ZBNF/NF practices, farmer-producers can get profit in two ways: firstly, by saving input costs, and secondly, by selling the produce at premium price. It may easily fetch a bit premium price, higher than conventional products, but lower than organic products, provided necessary institutional ecosystem is enabled to certify these fields. While in case of organic farming, verification of the land (conversion) is done for last three years, in case of ZBNF/NF, it may be certified only for the current cultivation year to ensure that no chemicals have been used in the field. Thus, as in case of any other non-food products, different product category can be created through institutional arrangements, so that farmer-producers as well as consumers can have more choices and farmers can capture the optimum value. Currently, producers and consumers are having two categories of agricultural produce- conventionally grown produce, in which farmers get very low price, or organic produce for which consumers pay very high price. The third category can easily be placed between these two, in the interests of producers as well as urban middle-income category population. Thus, the produce may be brought under PGS- Green certification to attract premium price.

Q2. Can ZBNF/NF practice help in ensuring food security of growing population in India?

A: As explained earlier, ZBNF/NF should not be construed as a panacea of all the problems, presently Indian agriculture is facing. This may be one of the alternative farming practices. There is no conclusive evidence stating increase or decrease in yield for all the crops in all types of agro-climatic conditions. It may or may not give higher crop yield than conventional/ chemical farming with modern cultivars/ hybrids and monoculture. When we talk about national goal of ensuring food security, increasing productivity and total production of similar products are the main objectives. However, this also creates near-perfect competition market, in which producers always compete on price, while consumers are benefitted with extremely low product prices, provided supply chain functions efficiently. The producers can get more than normal profit, only in case they can produce differentiated products. Therefore, narratives around ZBNF/NF practices need to be looked with different perspectives. The practices may be tested on 3 criteria: **a**. Whether cost of crop cultivation has reduced? **b.** Whether the crop is being produced without application of agro-chemicals, and finally, **c.** Does it require much less quantity of cow-dung and urine, in contrast to organic farming? If answer of all three questions are affirmative, the practice needs all support for its popularization.

Q3. How can all types of nutrients required by different types of crops be met through *Jeevamritha*, as the suggested practices recommend only 10 kg of cow dung in the form of *Jeevamritha* for 1-acre land?

A: This question has two parts: 1. Whether 10 kg cow-dung mixed in 200 litres of water in the form of *Jeevamritha* will be adequate for 1-acre cultivation? And, secondly, whether it will be sufficient for all types of crops to give desired yield. It may be noted that 10 kg of cow-dung suggested for 1-acre land in the ZBNF/NF practices can't be sufficient on standalone basis in supplying full nutrients to the crop. The cow dung microbial consortium includes bacteria, fungi and actinomycetes. When cow-dung is fermented with cow urine, pulses flour and jaggery, it triggers the process of multiplying these useful microbes available in cow-dung. These microorganisms are contemplated to be synthesizing nutrients from atmosphere, and make several other nutrients bio-available from soil system. However, in most of the cases, we observed that ZBNF-farmers are also adding FYM in their fields. Regarding second part, the proponent of ZBNF advocates for mixed cropping, and essentially not for monoculture. These crop combinations may complement each other, and thus the nutrients requirement may be less than that in case of monoculture.

Q4. From where farmers would get so much cow dung of indigenous cows?

A: From farmers' field survey, it was evident that farmers apply much less quantity of cow dung for cultivation of any crop as compared to that for organic farming. Thus, even when individual farmer is not having indigenous cow, the needed quantity of cow dung can be purchased from those farmers who are owning indigenous cows. From the field survey, it was observed that some farmers are doing ZBNF farming even without having indigenous cows. Either they purchase cow-dung and urine for preparing *Jeevamritha* and/or mix small quantity of cow-dung/ urine with that of other species like bullocks and buffaloes. At some places, new market potential for making and selling of *Jeevamritha/ Beejamritha* in the village has emerged, as many farmers may not like to handle cow dung and urine with their hands.

Q5. Why only indigenous cow breed and whether black indigenous cow is needed for ZBNF?

A: The indigenous Indian cow also contain higher amount of calcium, phosphorus, zinc and copper than the cross-breed cow (Garg and Mudgal 2007; Randhawa and Kullar 2011). Cow dung harbours a rich microbial diversity, containing different species of bacteria (Nene 1999). Cow dung microorganisms have shown natural ability to increase soil fertility through phosphate solubilization. Cow dung has antifungal substance that inhibits the growth of coprophilous fungi (Dhama *et al*., 2005). It also contains 24 different minerals and micro-nutrients. The indigenous cow also contains higher amount of calcium, phosphorus, zinc and copper than the cross-breed cow. Cow dung harbours a rich microbial diversity, containing different species of bacteria (*Bacillus spp*., *Corynebacterium spp*. and *Lactobacillus spp*.), protozoa and yeast (Saccharomyces and Candida) (Nene 1999; Randhawa and Kullar 2011). It is certainly evident that more detailed studies of cow dung are needed. On the other hand, it is a myth that ZBNF requires black cows. In fact, some of the farmers mix the dung and urine of different species, and apply in the field.

Q6. How ZBNF/NF practices can help increase farmers' income?

A: In addition to improving profitability through input cost saving and expected premium price for the produce, the producer-farmers can gain extra profit over the losses, if any due to reduction in crop yield. With the help of diversified/ mixed cropping practices as suggested under ZBNF/NF practices, farmers can harvest different types of produce at regular interval from small parcel of land and can earn regular income. However, to realise these benefits, different institutional arrangements are essential to identify the products under different category say with branding of PGS-Green, as mentioned earlier.

Q7. Is there any standardized practice under ZBNF/NF?

A: Though, the proponent of ZBNF recommends certain fixed package of practices to be adopted, the research team observed during the field survey that the farmers keep tweaking/customizing the recommended practices of ZBNF/NF, proposed by Sh. Subhas Palekar. Some of the important variations observed were; application of FYM in the field of ZBNF farm, using of dung & urines of bullocks/ buffaloes due to inconvenience in collection it separately, ignoring the irrigation timing (Wapsa) completely, cultivation of mixed/ inter-crops, application of mulching, use of local seeds, etc. Though, most of adopter-farmers apply *Jeevamritha* as replacement of chemical fertilizers, though the composition of *Jeevamritha* also varies at farmers' fields. Similarly, for controlling pests, different farmers adopt different materials to prepare the concoction to be sprayed, apart from biological control. Thus, there are no standardized practices under ZBNF/NF. Therefore, systematic research should be conducted at ICAR research institutes and/or agricultural universities to standardize the practices suiting to local conditions and desirable crop combinations.

Q8. Whether ZBNF/NF is suitable in diverse agro-climatic conditions and for different crops- cereals, pulses, fruits & vegetables, plantations, etc.?

A: The field survey under the study was conducted in three different states. While two districts of Andhra Pradesh state receive very good rainfall and have irrigation facility with red clay/ sandy loam soil, the selected districts in Maharashtra have entirely different situations- scanty rainfall, low irrigation facilities, and deep black soil. Apart from this, the farmers in the selected states- Andhra Pradesh, Karnataka and Maharashtra cultivated entirely different crop combinations- monoculture to as diverse as 5 to 9 (*Navdhanya*) crops simultaneously. Several news suggested that in Madhya Pradesh and Himachal Pradesh, farmers are adopting ZBNF practices in significant number. These observations support the argument that different crops under different agro-climatic conditions can be grown with ZBNF practices.

Q9. Can ZBNF/NF be applicable in rice-wheat system (monoculture)?

A: Agroecology-based farming method always recommends diversity in farming, so that crop, as well as soil biological diversity, can be maintained in the field for sustainability. Natural farming method is also one of the agroecology farming, thus it is always beneficial to have more than 1-2 crops simultaneously cultivated. There are several advantages from this strategy. It can reduce stress due to excessive mining of certain types of nutrients from the soil. It may give different types of produce for better household nutrition as well as regular income, in case their harvest is at different points of time. Therefore, ZBNF/NF practices may not be economically viable for large scale rice-wheat system.

Q10. Should ZBNF/NF practices be promoted at large scale in India?

A: This question is similar to Q.No. 1 & 2. According to our study and assessment, Natural Farming practices require preparation of *Jeevamritha* in bulk quantity and its application in regular interval, for large farm size, the unit cost economics due to use of hired labour may not be supportive. Secondly, it also requires monitoring of crop field in regular interval for weeding and pests' surveillance. In case of pest infestation, the preparation of organic insecticides becomes cumbersome process. Thirdly, chances of reduction in crop yield is quite imminent, in case farmers do not apply sufficient quantity of *Jeevamritha* or mulching. Large scale promotion of ZBNF practices may be counterproductive, keeping in view the increasing population and rising household income. Both factors trigger demand of larger quantity of food products in the country. Therefore, Natural Farming may be promoted as a sub-set of Organic Farming, and the products may be categorized as **Green Product** to attract premium price from high income households. Unless, the market and other institutional arrangement for its separate branding is not done, success of Natural Farming at large scale would be doubtful.

Q11. Whether ZBNF/NF farm practices are climate resilient?

A: It is interesting to learn that when asked such question to the adopting farmers, they expressed huge satisfaction stating that in drought conditions, while the neighbouring non-adopter farmers' fields got badly affected, their own crops fared well. Since ZBNF encourages mulching and addition of organic matter in the soil, soil system is believed to be much better than that of non-adopters' fields. Thus, it may be considered as climate resilient farming practices.

Q12. What benefits ZBNF/NF would bring to the farmers?

A: From the field survey and available literature, it appears that ZBNF/NF helps in increasing farm income, even when crop yield doesn't increase. Moreover, in the long run, if the theory of change proves to be true, it would help in a big way in regenerative agriculture. High level of microbial activity and improved Soil Organic Carbon, soil health would improve significantly. Apart from this, it might have several indirect benefits, such as non-application of chemical fertilizers would reduce the burden of fertilizer subsidy and stop nitrate leaching into the groundwater. Non-application of chemical pesticides helps farmers directly due to its non-exposure. On the other hand, crop diversity in the ZBNF field would also lead to better food diversity in the farmers' household, thus improving the nutritional status of the smallholder farmers. Therefore, non-chemical crop production with locally available resources may give better choice for both- farmers as well as consumers.

300% higher price of Organic flax seed as compared to conventional produce

50% higher price for Organic peanut over normal peanut

Dedicated shelf in the organised retail store for organic foods

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Annexure

Annexure I. State-wise percent distribution of micronutrient deficiencies in India

State	Zinc	Iron	Copper	Manganese	Boron
Andhra Pradesh	22.92	17.24	1.33	1.63	4.08
Arunachal Pradesh	4.63	1.44	1.4	3.01	39.15
Assam	28.11	0	2.8	0.01	32.75
Bihar	45.25	12	3.19	8.77	39.39
Chhattisgarh	25.59	7.06	3.22	14.77	20.59
Goa	55.29	12.21	3.09	16.91	12.94
Gujarat	36.56	25.87	0.38	0.46	18.72
Haryana	15.42	21.72	5.13	6.16	3.27
Himachal Pradesh	8.62	0.51	1.43	6.68	27.02
Jammu & Kashmir	10.91	0.41	0.34	4.6	43.03
Jharkhand	17.47	0.06	0.78	0.26	60
Karnataka	30.7	7.68	2.28	0.13	36.79
Kerala	18.34	1.23	0.45	3.58	31.21
Madhya Pradesh	57.05	8.34	0.47	2.25	4.3
Maharashtra	38.6	23.12	0.14	3.02	20.69
Manipur	11.5	2.13	2.46	2.06	37.17
Meghalaya	3.84	1.33	1.03	2.95	47.93
Mizoram	1.96	0.49	0.98	1.22	32.76
Nagaland	4.62	2	0.53	3.05	54.31
Odisha	32.12	6.42	7.11	2.12	51.88
Punjab	19.24	13.04	4.67	26.2	18.99
Rajasthan	56.51	34.38	9.15	28.28	2.99
Tamil Nadu	63.3	12.62	12.01	7.37	20.65
Telangana	26.77	16.65	1.36	3.54	16.49
Tripura	5.51	1.57	2.36	0	23.62
Uttar Pradesh	27.27	15.56	2.84	15.82	20.61
Uttarakhand	9.59	1.36	1.51	4.82	13.44
West Bengal	14.42	0.03	1.76	0.98	37.05
All India average	36.5	12.8	4.2	7.1	23.4

Source: Shukla et al (2018)

Annexure II. Protocol of measurements for soil chemical parameters

S. No.	Soil properties	Protocol	Reference
1.	Organic carbon	Wet digestion	Walkley and Black, 1934
2.	Available nitrogen	Kjeldahl method	Subbaiah and Asija, 1956
3.	Available phosphorus	0.5 M $NaHCO_3$ extraction	Olsen *et al.*, 1954
4.	Available potassium	Neutral normal ammonium extraction	Hanway and Heidal, 1952
5.	Exchangeable calcium	Ammonium acetate extraction	Lanyon and Heald, 1982
6.	Exchangeable magnesium	Ammonium acetate extraction	Lanyon and Heald, 1982
7.	Available sulphur	Turbidimetric method	Chesnin and Yien, 1950
8.	Available Boron	Azomethrine-H-hot water method	Berger and Truog, 1939
9.	DTPA-Zinc	DTPA-TEA-$CaCl_2$ extraction, AAS detection	Lindsay and Norvell, 1978
10.	DTPA-Iron	DTPA-TEA-$CaCl_2$ extraction, AAS detection	Lindsay and Norvell, 1978
11.	DTPA-Copper	DTPA-TEA-$CaCl_2$ extraction, AAS detection	Lindsay and Norvell, 1978
12.	DTPA-Manganese	DTPA-TEA-$CaCl_2$ extraction, AAS detection	Lindsay and Norvell, 1978

Annexure III. Farming practices adopted by farmers selected for soil and plant analysis in Vizianagaram district

S.No.	Village code	Farming type	Practices	Soil type
1.	GRL	NF	Goat manure (0.5 t ha^{-1})+ JM (500 l ha^{-1}/15 days interval)+ GM (*dhaincha*)	Mixed black
		Non-NF	FYM (2 t ha^{-1})+ Urea (75 kg ha^{-1}) + DAP (25 kg ha^{-1})+ MOP (25 kg ha^{-1})+ GM (*dhaincha*)	Mixed black
2.	PTD	NF	GJM (0.5 t ha^{-1})+ JM (500 l/ha^{-1}/ 15 days interval)+ *Beejamritha* (seed treatment)	Mixed black
		Non-NF	FYM (2 t ha^{-1})+Urea (100 kg ha^{-1})+ DAP (50 kg)+ MOP (60 kg ha^{-1})	Mixed black
3.	PSRP	NF	FYM (1 t ha^{-1})+GJM (0.6 t ha^{-1}) +JM (500 l ha^{-1})+GM (*dhaincha*)+ Azolla application	Mixed black
		Non-NF	FYM (2 t ha^{-1})+ Urea (100 kg ha^{-1})+ DAP(50 kg ha^{-1}) +Azolla application+ GM (*dhaincha*)	Mixed black
4.	PDSL	NF	GJM (0.6 t ha^{-1})+ JM (500 l ha^{1}/ 15 days) + GM (*dhaincha*)+ Neemastram (every 20 days interval)+*Beejamritha* (seed treatment)	Mixed black
		Non-NF	FYM (2 t ha^{-1}) + Urea (100 kg ha^{-1})+ DAP (50 kg ha^{-1})+GM (*dhaincha*)	Mixed black
5.	KGP	NF	GJM (0.5 t ha^{-1})+JM (500 l ha^{-1}) +Neemastram (every 20 days interval)	Mixed black
		Non-NF	FYM (2 t ha^{-1})+Urea (50 kg ha^{-1} +DAP (50 kg ha^{-1})	Mixed black
6.	SKR	NF	GJM (0.6 t ha^{-1})+ JM (500 l ha^{-1}) + Neemastram (every 30 days interval)	Mixed black
		Non-NF	FYM (3 t ha^{-1})+Urea (50 kg ha^{-1}) +DAP (75 kg ha^{-1})	Mixed black
7.	GLD	NF	FYM (1 t ha^{-1})+ GJM (0.5 t ha^{-1}) + JM (500 l ha^{-1}/15days intervals)+ *Beejamritha* (seed treatment)	Red
		Non-NF	FYM (2 t ha^{-1})+Urea (100 kg ha^{-1}) + DAP (50 kg ha^{-1})	Red
8.	AGR	NF	FYM (1 t ha^{-1})+ JM (500 l ha^{-1})+ *Beejamritha* (seed treatment)	Mixed black
		Non-NF	FYM (1 t ha^{-1})+Compost (0.5 t ha^{-1}) +Urea (100 kg ha^{-1}) +DAP (100 kg ha^{-1})	Mixed black
9.	KDP	NF	GJM (0.5 t ha^{-1})+JM (500 l ha^{-1}/ 15 days intervals)+Panchgavya spray+ *Beejamritha* (seed treatment)	Mixed black
		Non-NF	Urea (100 kg ha^{-1})+DAP (75 kg ha^{-1}) +MOP (25 kg ha^{-1})+zinc sulphate (25 kg ha^{-1})+ Azolla application	Mixed black
10.	PTR	NF	GJM (0.5 t ha^{-1})+GM (500 l/ha^{-1}/ 15 days intervals)+ Azolla application	Mixed black
		Non-NF	FYM (1 t ha^{-1})+Urea (100 kg ha^{-1})+DAP (100 kg ha^{-1})+ Azolla application	Mixed black
11.	GLN	NF	GJM (0.4 t ha^{-1})+GM (500 l ha^{-1}) +GM (*dhaincha*)+ Azolla application	Mixed black
		Non-NF	FYM (1 t ha^{-1})+Urea (100 kg ha^{-1}) +DAP (50 kg ha^{-1})+ GM (*dhaincha*)+ Azolla application	Mixed black

JM=Jeevamritha; GJM=GhanJeevamritha; GM=Green manuring; FYM=Farmyard manure; DAP=Diammonium phosphate; MOP=Murate of potash

Name of Village: GRL= Gurala; PTD= Pettada; PSRP= PSR Puram; PDSL= Pidiseela; KGP= Konda Ganga Pudi; SKR= S. Kotasita Ramapuram; GLD= Galendagond; AGR= Aaguru; KDP= Kovvadapeta; PTR= Paturu; GLN= Golgaon

Annexure IVa. Plot-wise availability of soil organic carbon (SOC) and major nutrients in paddy cultivated fields in Vizianagaram district

S.No	Village code	SOC (%)		N (kg/ha)		P (kg/ha)		K (kg/ha)	
		NF	Non-NF	NF	Non-NF	NF	Non-NF	NF	Non-NF
1	GRL	0.67	0.78	194	220	35	44	171	248
2	PTD	0.40	0.61	207	232	31	39	123	141
3	PSRP	0.63	0.75	157	194	20	37	188	225
4	PDSL	0.50	0.68	207	220	18	23	142	229
5	KGP	0.65	0.71	169	194	23	29	155	191
6	SKR	0.50	0.76	169	207	24	32	161	225
7	GLD	0.70	0.87	220	244	33	38	175	226
8	AGR	0.81	0.71	298	283	33	28	254	213
9	KDP	0.74	0.88	260	294	29	35	255	306
10	PTR	0.44	0.48	248	263	18	22	162	173
11	GLN	0.67	0.78	194	220	35	44	171	248
	Range (n=11)	0.40-0.81	0.48-0.88	157-298	194-294	18-35	22-44	123-255	141-306
	Mean	0.61	0.73	211	234	27	34	178	220
	SD	0.13	0.11	43	34	7	8	42	43

Annexure IVb. Plot-wise availability of secondary nutrients in paddy cultivated fields in Vizianagaram district

S.No	Village Code	S (kg ha^{-1})		Ca (meq 100 g^{-1})		Mg (meq 100 g^{-1})	
		NF	Non-NF	NF	Non-NF	NF	Non-NF
1	GRL	16.1	17.8	19.6	20.4	5.0	6.1
2	PTD	12.4	11.9	17.8	16.6	4.4	4.2
3	PSRP	23.5	25.9	18.0	19.0	7.2	7.8
4	PDSL	19.2	24.1	12.2	11.4	5.2	4.9
5	KGP	17.8	17.1	17.4	18.8	6.6	7.2
6	SKR	22.4	23.7	11.0	12.2	5.2	6.6
7	GLD	12.8	15.7	5.8	6.2	2.2	2.6
8	AGR	27.5	29.1	6.8	7.9	2.2	2.5
9	KDP	32.5	31.6	6.5	8.2	2.3	2.6
10	PTR	23.6	25.9	10.5	11.3	3.8	4.8
11	GLN	18.9	20.8	16.6	18.4	5.0	6.3
Range (n=11)		12.4-32.5	11.9-31.6	5.8-19.6	6.2-20.4	2.2-7.2	2.5-7.8
	Mean	20.61	22.15	12.93	13.67	4.46	5.05
	SD	6.09	6.04	5.17	5.13	1.71	1.91

Annexure IVc. Plot-wise availability of soil micronutrients in paddy cultivated fields in Vizianagaram district

S. No	Village code	Fe (mg/kg)		Mn (mg/kg)		Cu (mg/kg)		Zn (mg/kg)		B (mg/kg)	
		NF	Non-NF	NF	Non-NF	NF	Non-NF	NF	Non-NF	NF	Non-NF
1	GRL	40.1	25.9	9.4	6.0	2.20	2.15	0.84	1.07	0.57	0.62
2	PTD	23.5	23.5	7.0	7.5	1.72	1.60	1.71	2.34	0.46	0.51
3	PSRP	26.0	23.3	8.3	6.1	1.51	1.73	1.10	2.19	0.63	0.66
4	PDSL	19.7	41.1	7.3	5.6	1.64	1.46	1.38	1.13	0.68	0.73
5	KGP	56.7	48.2	6.3	10.9	1.21	1.87	1.56	2.14	0.56	0.55
6	SKR	59.1	49.2	7.9	10.2	1.35	1.89	1.58	1.64	0.67	0.70
7	GLD	97.2	116.1	19.0	35.8	1.76	2.91	1.41	2.97	0.75	0.81
8	AGR	64.0	71.1	27.5	33.8	4.08	7.08	0.48	0.58	0.84	0.87
9	KDP	80.5	34.9	14.5	32.6	4.16	9.04	0.26	0.34	0.73	0.71
10	PTR	46.1	71.4	9.6	5.6	9.16	11.20	0.46	0.74	0.77	0.82
11	GLN	29.9	40.9	9.4	6.0	2.20	2.15	1.07	0.84	0.84	0.79
	Range (n=11)	19.7-97.2	23.3-116.1	6.3-27.5	5.6-35.8	1.21-9.16	1.46-11.20	0.26-1.71	0.34-2.97	0.46-0.84	0.51-0.87
	Mean	49.3	49.6	11.5	14.6	2.82	3.92	1.08	1.45	0.68	0.71
	SD	24.9	27.7	6.5	12.7	2.34	3.48	0.51	0.85	0.12	0.11

Annexure IVd. Plot-wise soil microbial population in paddy cultivated fields in Vizianagaram district

S. No.	Village code	Bacteria (Log_{10} CFU/g soil)		Fungi (Log_{10} CFU/g soil)		Actinomycetes (Log_{10} CFU/g soil)	
		NF	Non-NF	NF	Non-NF	NF	Non-NF
1	GRL	8.00	8.18	4.06	4.76	4.78	4.40
2	PTD	8.85	7.00	4.06	4.86	3.70	4.00
3	PSRP	9.04	8.54	4.02	4.34	4.85	4.48
4	PDSL	8.40	8.00	3.90	4.00	4.54	4.54
5	KGP	8.54	8.40	4.19	3.18	4.40	4.40
6	SKR	8.30	8.93	4.22	4.32	3.70	4.39
7	GLD	8.40	9.79	4.24	4.24	4.65	4.40
8	AGR	9.13	9.41	3.54	4.30	4.40	4.74
9	KDP	9.41	8.81	4.87	3.81	4.54	4.88
10	PTR	9.04	9.04	4.13	3.95	4.70	4.54
11	GLN	8.78	8.85	3.18	3.18	4.54	4.18
	Range (n=11)	8.00-9.41	7.00-9.79	3.18-4.87	3.18-4.86	3.70-4.85	4.00-4.88
	Mean	8.72	8.63	4.04	4.09	4.44	4.45
	SD	0.40	0.71	0.40	0.52	0.37	0.23

Annexure IVe. Plot-wise soil microbial population in paddy cultivated fields in Vizianagaram district

S. No.	Village code	Free-living Nitrogen-fixing bacteria (Log_{10} CFU/g soil)		Phosphorus solublizing bacteria (Log_{10} CFU/g soil)		*Pseudomonas* sp. (Log_{10} CFU/g soil)	
		NF	Non-NF	NF	Non-NF	NF	Non-NF
1	GRL	5.02	3.70	3.48	3.65	6.18	6.00
2	PTD	5.66	4.98	3.30	3.30	6.40	6.81
3	PSRP	5.15	4.30	3.65	3.74	6.18	6.30
4	PDSL	4.93	5.13	3.60	3.40	6.48	6.40
5	KGP	5.02	4.00	3.40	3.81	6.65	6.18
6	SKR	4.00	5.16	3.48	4.60	6.40	6.39
7	GLD	5.79	4.54	3.48	3.18	6.30	5.70
8	AGR	5.47	5.44	2.70	3.88	5.00	5.70
9	KDP	5.31	5.16	3.18	3.70	6.00	7.26
10	PTR	5.04	5.10	3.00	3.30	5.70	5.70
11	GLN	5.35	4.78	2.70	3.85	6.24	6.23
Range (n=11)		4.00-5.79	3.70-5.44	2.70-3.65	3.18-4.10	5.00-6.65	5.70-7.26
	Mean	5.16	4.75	3.27	3.67	6.14	6.24
	SD	0.45	0.53	0.32	0.38	0.43	0.46

Annexure IVf. Plot-wise plant nutrient contents in paddy plants in Vizianagaram district

S. No	Village code	N (%)		P (%)		K (%)		Fe (mg/kg)		Mn (mg/kg)		Cu (mg/kg)		Zn (mg/kg)		B (mg/kg)	
		NF	Non-NF	NF	Non-NF	NF	Non-NF	NF	Non-NF	NF	Non-NF	NF	Non-NF	NF	Non-NF	NF	Non-NF
1	GRL	0.71	0.74	0.31	0.33	1.10	1.12	52.0	54.0	40.0	51.0	6.2	8.1	21.0	24.5	23.1	24.9
2	PTD	0.68	0.76	0.36	0.40	0.71	0.82	59.0	68.0	32.0	41.0	7.2	5.1	27.5	27.9	31.3	33.2
3	PSRP	0.87	0.92	0.29	0.31	0.98	0.96	57.0	51.0	55.0	48.0	8.4	6.2	22.0	19.6	24.6	28.5
4	PDSL	0.85	0.94	0.45	0.51	0.84	0.89	67.0	62.0	26.0	24.0	5.4	6.5	31.2	28.6	17.5	19.8
5	KGP	0.76	0.74	0.46	0.42	0.79	0.92	57.0	69.0	25.0	31.0	6.5	7.8	27.1	22.4	34.9	38.0
6	SKR	0.79	0.75	0.35	0.31	0.94	0.92	68.0	77.0	28.0	32.0	8.2	6.4	26.1	31.4	24.9	28.4
7	GLD	0.89	0.88	0.36	0.42	0.87	0.96	54.0	53.0	24.0	21.0	7.6	7.1	22.1	24.5	37.2	36.9
Range (n=7)		0.68-0.89	0.74-0.94	0.29-0.46	0.31-0.51	0.71-1.10	0.82-1.12	52.0-68.0	51.0-77.0	24.0-55.0	21.0-51.0	5.4-8.4	5.1-8.1	21.0-31.2	19.6-31.4	17.5-37.2	19.8-38.0
Mean		0.79	0.82	0.37	0.39	0.89	0.94	59.1	62.0	32.9	35.4	7.1	6.7	25.3	25.6	27.6	30.0
SD		0.08	0.09	0.06	0.07	0.13	0.09	6.1	9.8	11.2	11.6	1.1	1.0	3.7	4.0	7.0	6.5

Annexure V. Farming practices adopted by farmers selected for soil and plant analysis in Visakhapatnam district

S. No	Village code	Farming type	Practices	Soil type
	Paddy grower			
1.	DBM	NF	GJM (0.5 t ha^{-1})+ JM 500 l ha^{-1}/15 days intervals+ Azolla application+ GM (*dhaincha*)	Mixed black
		Non-NF	FYM (2.5 t ha^{-1})+100 kg urea+DAP (50 kg ha^{-1})+GM (*dhaincha*)+Azolla application	Mixed black
2.	VPM	NF	GJM (0.5 t ha^{-1})+ JM (500 l ha^{-1}/15 days intervals)+ Azolla application+*Beejamritha* (seed treatment)	Mixed black
		Non-NF	FYM (3 t ha^{-1})+ Urea (100 kg ha^{-1})+ DAP (50 kg ha^{-1})+ GM (*dhaincha*)	Mixed black
3.	KNM	NF	GJM (0.5 t ha^{-1})+ JM (500 l ha^{-1}/15days intervals)+ Azolla aplication+GM (*dhaincha*)	Mixed black
		Non-NF	FYM (1 t ha^{-1})+Urea (100kg ha^{-1})+DAP (50 kg ha^{-1})+ Azolla application +GM (*dhaincha*)	Mixed black
4.	JVM	NF	FYM (1 t ha^{-1})+GJM (0.4 t ha^{-1})+JM (500 l/15days intervals)+ *Nemastram* every 30 days intervals+ *Beejamritha* (seed treatment)	Mixed black
		Non-NF	FYM (2 t ha^{-1})+Urea (75 kg ha^{-1})	Mixed black
5.	CGD	NF	GJM (0.5 t ha^{-1})+JM (500 l ha^{-1}/ 15 days intervals)	Red
		Non-NF	Urea (100 kg ha^{-1})+DAP (50 kg ha^{-1})+MOP (50 kg ha^{1}) + *Beejamritha* (seed treatment)	Red
6.	MPM	NF	FYM (1 t ha^{-1})+ compost (0.5 t ha^{-1}) +JM (400 l ha^{-1}/ 15 days intervals)	Black
		Non-NF	FYM (2 t ha^{-1})+Urea (75 kg ha^{-1})+DAP (75 kg ha^{-1})	Black
7.	CDA	NF	Compost (0.5 t ha^{-1})+GJM (0.2 t ha^{-1}) +JM (500 l ha^{-1}/ 20 days intervals) + *Beejamritha* (seed treatment)	Black
		Non-NF	FYM (1 t ha^{-1})+ Urea (100 kg ha^{-1})+DAP (50 kg ha^{-1})	Black
8.	RRP	NF	FYM (1 t ha^{-1}) +JM (500 l ha^{-1}/15 days intervals)	Mixed black
		Non-NF	FYM (1 t ha^{-1})+Urea (100 kg ha^{-1}) +DAP (50 kg ha^{-1})	Mixed black
	Sugarcane growers			
9.	VPM	NF	GJM (0.5 t ha^{-1})+ JM (500 l ha^{-1}/15 days intervals)+ GM (*dhaincha*)+ mulching with sugarcane trashes	Mixed red
		Non-NF	FYM (3 t ha^{-1})+Urea (50 kg ha^{-1}) +GM (*dhaincha*)+ mulching with sugarcane trashes	Mixed red
10.	JVM	NF	GJM (1 t ha^{-1})+JM (500 l ha^{-1}/15days intervals)+ Nemastram every 60 days intervals+ mulching with sugarcane trashes	Mixed red
		Non-NF	FYM (3 t ha^{-1})+ Urea (100 kg ha^{-1})+DAP (50 kg ha^{-1})+ mulching with sugarcane trashes	Mixed red
11.	KPL	NF	GJM (1 t ha^{-1})+JM (500 l ha^{-1}/15days intervals)+ mulching with sugarcane trashes	Mixed red
		Non-NF	FYM (4 t ha^{-1})+Urea (100 kg ha^{-1})+ DAP (50 kg ha^{-1}) +mulching with sugarcane trashes	Mixed red

JM=Jeevamritha; GJM=GhanJeevamritha; GM=Green manuring; FYM=Farmyard manure; DAP=Diammonium phosphate; MOP=Murate of potash

Name of Village: DBM=Dibbapallam; VPM=Vinkpalam; KNM=Konam; JVM=Jaithavaram; CGD=Channagogada; MPM=Mukundapuram; CDA=Cheedikada; RRP=R R Peta; KPL=Kandi Palli

Annexure VIa. Plot-wise availability of soil organic carbon (SOC) and major nutrients in paddy cultivated fields in Visakhapatnam district

S.No	Village code	SOC (%)		N (kg/ha)		P (kg/ha)		K (kg/ha)	
		NF	Non-NF	NF	Non-NF	NF	Non-NF	NF	Non-NF
1	DBM	0.53	0.57	141	156	25	29	125	126
2	VPM	0.52	0.47	119	106	49	46	346	373
3	KNM	0.76	0.81	220	232	24	32	310	319
4	JVM	0.64	0.68	194	219	23	32	283	312
5	CGD	0.71	0.62	220	182	27	19	360	328
6	MPM	0.64	0.72	210	240	25	29	251	325
7	CDA	0.79	0.84	266	316	23	29	327	371
8	RRP	0.65	0.7	216	260	33	35	186	232
	Range (n=8)	0.52-0.79	0.47-0.84	119-266	106-316	23-49	19-46	125-360	126-373
	Mean	0.66	0.68	198	214	29	31	274	298
	SD	0.10	0.12	47	65	9	8	82	82

Annexure VIb. Plot-wise availability of secondary nutrients in paddy cultivated fields in Vishakapatnam district

S.No	Village Code	S (kg ha^{-1})		Ca (meq 100g^{-1})		Mg (meq 100g^{-1})	
		NF	Non-NF	NF	Non-NF	NF	Non-NF
1	DPL	22.1	24.5	11.0	13.0	4.2	5.2
2	VPL	16.5	17.8	16.4	17.1	5.1	4.9
3	KNM	27.9	30.4	11.0	12.4	5.8	6.0
4	JVM	18.2	16.9	14.4	15.5	5.2	5.6
5	CGD	18.9	21.6	9.6	11.2	6.4	7.1
6	MPM	23.4	22.6	13.8	14.2	3.4	4.0
7	CKD	32.8	37.5	14.9	16.0	6.5	6.1
8	RRP	26.3	29.0	11.1	12.0	4.3	5.8
Range (n=8)		16.5-32.8	16.9-37.5	9.6-16.4	11.2-17.1	3.4-6.5	4.0-7.1
	Mean	23.3	25.0	12.78	13.93	5.11	5.59
	SD	5.5	6.9	2.41	2.11	1.10	0.92

Annexure VIc. Plot-wise availability of soil micronutrients in paddy cultivated fields in Visakhapatnam district

S.No	Village code	Fe (mg/kg)		Mn (mg/kg)		Cu (mg/kg)		Zn (mg/kg)		B (mg/kg)	
		NF	Non-NF	NF	Non-NF	NF	Non-NF	NF	Non-NF	NF	Non-NF
1	DBM	14.3	11.5	14.7	8.0	0.90	2.31	1.35	1.62	0.51	0.57
2	VPM	31.5	41.9	16.4	19.4	2.05	0.97	1.66	2.88	0.46	0.52
3	KNM	40.7	53.6	38.0	22.6	1.28	1.04	0.81	0.93	0.39	0.45
4	JVM	62.0	49.5	10.0	12.1	1.02	1.59	2.14	1.37	0.62	0.58
5	CGD	57.7	51.4	17.4	11.6	1.27	1.37	3.24	2.95	0.68	0.73
6	MPM	34.3	52.2	15.0	24.7	2.92	2.44	2.70	3.42	0.72	0.76
7	CDA	55.4	49.3	30.3	35.4	1.60	1.84	2.52	2.74	0.45	0.42
8	RRP	64.5	57.3	33.7	22.0	1.40	2.04	3.10	2.48	0.57	0.64
	Range (n=8)	14.3-64.5	11.5-57.3	10.0-38.0	8.0-35.4	0.90-2.92	0.97-2.44	0.81-3.24	0.93-3.42	0.39-0.72	0.42-0.76
	Mean	45.1	45.8	21.9	19.5	1.56	1.70	2.19	2.30	0.55	0.58
	SD	17.7	14.6	10.4	8.8	0.66	0.55	0.86	0.88	0.12	0.12

Annexure VId. Plot-wise availability of soil organic carbon (SOC) and major nutrients in sugarcane cultivated fields in Visakhapatnam district

S. No	Village code	SOC (%)		N (kg/ha)		P (kg/ha)		K (kg/ha)	
		NF	Non-NF	NF	Non-NF	NF	Non-NF	NF	Non-NF
1	VPM	0.62	0.71	144	157	19	22	195	216
2	JVM	0.61	0.67	169	194	18	23	251	260
3	KPL	0.72	0.78	182	215	26	21	306	318
	Range (n=3)	0.61-0.72	0.67-0.78	144-182	157-215	18-26	21-23	195-306	216-318
	Mean	0.65	0.72	165	189	21	22	251	265
	SD	0.06	0.06	19	29	4	1	56	51

Annexure VIe. Plot-wise availability of secondary nutrients in sugarcane cultivated fields in Visakhapatnam district

S.No	Village Code	S ($kg\ ha^{-1}$)		Ca ($meq\ 100g^{-1}$)		Mg ($meq\ 100g^{-1}$)	
		NF	Non-NF	NF	Non-NF	NF	Non-NF
1	VPM	18.9	22.6	11.8	10.0	7.2	6.0
2	JVM	23.4	24.1	14.2	16.4	5.8	6.9
3	KPL	17.6	16.8	13.0	14.4	7.0	8.7
Range (n=3)		17.6-23.4	16.8-24.1	11.8-14.2	10-16.4	5.8-7.2	6.0-8.7
	Mean	20.0	21.2	13.00	13.60	6.67	7.20
	SD	3.0	3.9	1.20	3.27	0.76	1.37

Annexure VIf. Plot-wise availability of soil micronutrients in sugarcane cultivated fields in Visakhapatnam district

S. No	Village code	Fe (mg/kg)		Mn (mg/kg)		Cu (mg/kg)		Zn (mg/kg)		B (mg/kg)	
		NF	Non-NF	NF	Non-NF	NF	Non-NF	NF	Non-NF	NF	Non-NF
1	VPM	6.7	12.5	6.9	9.3	1.11	0.69	2.16	0.85	0.45	0.49
2	JVM	10.5	13.9	7.8	10.5	1.13	0.63	3.62	2.25	0.55	0.56
3	KPL	6.8	8.1	5.4	4.2	0.90	0.79	1.16	0.49	0.62	0.68
Range (n=3)		6.7-10.5	8.1-13.9	5.4-7.8	4.2-10.5	0.90-1.13	0.63-0.79	1.16-3.62	0.49-2.25	0.45-0.62	0.49-0.68
	Mean	8.0	11.5	6.7	8.0	1.05	0.70	1.05	0.70	0.54	0.58
	SD	2.2	3.0	1.2	3.3	0.13	0.08	1.24	0.93	0.09	0.10

Annexure VIg. Plot-wise soil microbial population in paddy cultivated fields in Visakhapatnam district

S. No.	Village Code	Bacteria (Log_{10} CFU g^{-1} soil)		Fungi (Log_{10} CFU g^{-1} soil)		Actinomycetes (Log_{10} CFU g^{-1} soil)	
		NF	Non-NF	NF	Non-NF	NF	Non-NF
1	DPL	8.60	9.15	3.88	3.98	5.00	5.02
2	VPL	8.70	8.30	3.85	4.04	3.48	4.00
3	KNM	8.30	8.30	4.24	4.48	4.40	4.85
4	JVM	8.00	8.30	3.7	4.59	4.95	5.11
5	CGD	8.18	8.40	4.46	4.56	5.00	4.81
6	MPM	9.36	8.18	3.6	4.31	3.00	3.18
7	CKD	8.18	8.00	3.65	3.3	3.54	3.48
8	RRP	8.40	8.18	3.4	2.7	3.00	2.70
Range (n=8)		8.00-9.36	8.00-9.15	3.40-4.46	2.70-4.59	3.00-5.00	2.70-5.11
Mean		8.47	8.35	3.85	4.00	4.05	4.14
SD		0.40	0.32	0.33	0.63	0.83	0.87

Annexure VIh. Plot-wise soil microbial population in paddy cultivated fields in Visakhapatnam district

S. No.	Village Code	Free-living Nitrogen-fixing bacteria (Log_{10} CFU g^{-1} soil)		Phosphorus solubilizing bacteria (Log_{10} CFU g^{-1} soil)		*Pseudomonas* sp. (Log_{10} CFU g^{-1} soil)		*Trichoderma sp.* (Log_{10} CFU g^{-1} soil)	
		NF	Non-NF	NF	Non-NF	NF	Non-NF	NF	Non-NF
1	DPL	5.16	5.29	2.70	3.40	6.54	6.70	3.10	3.23
2	VPL	5.04	5.02	3.93	3.90	6.18	6.48	3.36	2.81
3	KNM	4.90	5.79	3.60	3.48	6.48	6.65	3.00	3.48
4	JVM	5.49	5.51	3.74	3.48	6.30	6.18	2.93	2.00
5	CGD	5.18	4.00	3.40	3.40	6.30	6.18	2.54	3.59
6	MPM	5.76	4.90	3.30	3.74	6.60	6.65	3.18	4.31
7	CKD	5.30	4.93	4.15	3.40	7.10	6.54	4.11	3.30
8	RRP	4.60	4.60	3.00	3.30	6.60	5.70	3.18	3.30
Range (n=8)		4.60-5.76	4.00-5.79	2.70-4.15	3.30-3.90	6.18-7.10	5.70-6.70	2.54-4.11	2.00-4.31
	Mean	5.18	5.01	3.48	3.51	6.51	6.39	3.18	3.25
	SD	0.33	0.52	0.45	0.19	0.27	0.32	0.42	0.62

Annexure VIi. Plot-wise soil microbial population in sugarcane cultivated fields in Visakhapatnam district

S. No.	Village code	Bacteria (Log_{10} CFU g^{-1} soil)		Fungi (Log_{10} CFU g^{-1} soil)		Actinomycetes (Log_{10} CFU g^{-1} soil)	
		NF	Non-NF	NF	Non-NF	NF	Non-NF
1	VPM	8.18	9.24	4.15	4.34	4.98	4.90
2	JVM	8.18	8.18	4.13	3.98	5.02	4.88
3	KPL	8.40	8.00	4.30	3.90	5.00	4.18
	Range (n=3)	8.18-8.40	8.00-9.24	4.13-4.30	3.90-4.34	4.98-5.02	4.18-4.90
	Mean	8.25	8.33	4.19	4.07	5.00	4.65
	SD	0.10	0.05	0.08	0.19	0.02	0.33

Annexure VIj. Plot-wise soil microbial population in sugarcane cultivated fields in Visakhapatnam district

S. No.	Village code	Free-living Nitrogen-fixing bacteria (Log_{10} CFU g^{-1} soil)		Phosphorus solubilizing bacteria (Log_{10} CFU g^{-1} soil)		*Pseudomonas* sp. (Log_{10} CFU g^{-1} soil)		*Trichoderma sp.* (Log_{10} CFU g^{-1} soil)	
		NF	Non-NF	NF	Non-NF	NF	Non-NF	NF	Non-NF
1	VPM	5.04	4.78	3.65	3.74	6.00	6.18	3.41	3.02
2	JVM	5.60	5.32	3.74	3.70	6.54	6.40	2.00	2.00
3	KPL	5.60	4.70	3.54	3.54	6.18	6.81	2.74	2.65
	Range (n=3)	5.04-5.60	4.70-5.32	3.54-3.74	3.54-3.74	6.00-6.54	6.18-6.81	2.00-3.41	2.00-3.02
	Mean	5.41	4.93	3.64	3.66	6.24	6.46	2.72	2.56
	SD	0.26	0.28	0.08	0.09	0.22	0.26	0.58	0.42

Annexure VIk. Plot-wise plant nutrient contents in paddy plants in Visakhapatnam district

S.No	Village Code	N (%)		P (%)		K (%)	
		NF	Non-NF	NF	Non-NF	NF	Non-NF
1	DPM	0.69	0.76	0.21	0.26	0.77	0.72
2	VPM	0.72	0.84	0.32	0.24	0.82	0.84
3	KNM	0.86	0.98	0.34	0.26	0.82	0.91
4	JVM	0.76	0.89	0.32	0.29	0.85	0.78
5	CDA	0.68	0.79	0.27	0.34	0.86	0.79
Range (n=5)		0.68-0.86	0.76-0.98	0.21-0.34	0.24-0.34	0.77-0.86	0.72-0.91
	Mean	0.74	0.85	0.29	0.28	0.82	0.81
	SD	0.07	0.09	0.05	0.04	0.04	0.07

Annexure VIl. Plot-wise plant micro-nutrient contents in paddy plants in Visakhapatnam district

S. No.	Village Code	Fe (mg kg-1)		Mn (mg kg-1)		Cu (mg kg-1)		Zn (mg kg-1)		B (mg kg-1)	
		NF	Non-NF	NF	Non-NF	NF	Non-NF	NF	Non-NF	NF	Non-NF
1	DPM	51.6	48.2	26.2	24.4	6.4	6.9	21.5	19.8	23.4	26.7
2	VPM	55.3	59.5	31.1	39.5	7.1	7.8	25.4	21.4	18.8	24.3
3	KNM	41.2	57.9	29.1	36.6	4.2	7.8	22.4	26.5	29.0	27.9
4	JVM	54.3	67.5	25.2	29.4	5.4	7.4	24.5	18.7	26.5	31.7
5	CDA	45.7	43.1	34.5	21.4	5.8	6.4	26.5	19.8	32.3	30.9
	Range (n=5)	41.2-55.3	43.1-67.5	25.2-34.5	21.4-39.5	4.2-7.1	6.4-7.8	21.5-26.5	18.7-26.5	18.8-32.3	24.3-31.7
	Mean	49.6	55.2	29.2	30.3	5.8	7.3	24.1	21.2	26.0	28.3
	SD	6.0	9.6	3.8	7.7	1.1	0.6	2.1	3.1	5.2	3.0

Annexure VIm. Plot-wise plant nutrient contents in sugarcane plants in Visakhapatnam district

S. No	Village Code	N (%)		P (%)		K (%)	
		NF	Non-NF	NF	Non-NF	NF	Non-NF
1	KPL	0.82	0.86	0.37	0.34	0.74	0.81
2	VPM	0.92	0.88	0.31	0.39	0.84	0.95
3	JVM	0.75	0.77	0.31	0.36	0.74	0.68
Range (n=3)		0.75-0.92	0.77-0.88	0.31-0.37	0.34-0.39	0.74-0.84	0.68-0.95
	Mean	0.83	0.84	0.33	0.36	0.77	0.81
	SD	0.09	0.06	0.03	0.03	0.06	0.14

Annexure VIn. Plot-wise plant micro-nutrient contents in sugarcane plants in Visakhapatnam district

Sl. No	Village Code	Fe (mg kg-1)		Mn (mg kg-1)		Cu (mgkg-1)		Zn (mg kg-1)		B (mg kg-1)	
		NF	Non-NF	NF	Non-NF	NF	Non-NF	NF	Non-NF	NF	Non-NF
1	KPL	44.6	52.1	28.5	27.9	7.4	8.1	15.4	21.4	32.6	34.5
2	VPM	53.7	49.5	22.4	25.7	5.4	6.5	17.4	26.5	26.7	29.0
3	JVM	54.9	58.7	31.4	24.5	4.2	6.5	14.5	12.5	23.5	22.9
	Range (n=3)	44.6-54.9	49.5-58.7	22.4-31.4	24.5-27.9	4.2-7.4	6.5-8.1	14.5-17.4	12.5-26.5	23.5-32.6	22.9-34.5
	Mean	51.1	53.4	27.4	26.0	5.7	7.0	15.8	20.1	27.6	28.8
	SD	5.6	4.7	4.6	1.7	1.6	0.9	1.5	7.1	4.6	5.8

Annexure VIo Village-wise nutrient contents of *jeevamritha* samples collected from Andhra Pradesh

S. No.	Village Code	OC (%)	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	Fe (mg/l)	Zn (mg/l)	Mn (mg/l)	Cu (mg/l)
1.	KNM	0.27	0.04	0.020	0.06	0.04	0.03	0.015	34.1	2.1	1.8	1.1
2.	KPL	0.28	0.06	0.021	0.05	traces	0.02	0.016	41.2	1.8	1.9	1.8
3.	DPL	0.22	0.05	0.019	0.05	0.03	0.02	0.014	45.7	1.6	traces	traces
4.	VPM	0.24	0.04	0.017	0.04	0.04	0.03	0.017	38.6	traces	traces	1.2
5.	CDA	0.19	0.04	0.020	0.06	traces	0.02	0.015	34.1	traces	1.4	1.9
6.	JVM	0.26	0.03	0.021	0.05	traces	traces	0.012	29.8	traces	traces	1.4
7.	SKR	0.22	0.06	0.018	0.06	0.05	0.03	0.016	32.1	1.7	1.1	traces
Range (n=7)		0.19-0.28	0.03-0.06	0.017-0.021	0.04-0.06	0.03-0.05	0.02-0.03	0.012-0.017	29.8-45.7	1.6-2.1	1.1-1.9	1.1-1.9
Mean		0.240	0.046	0.019	0.053	0.040	0.025	0.015	36.5	1.8	1.6	1.5
SD		0.032	0.011	0.002	0.008	0.008	0.005	0.002	5.6	0.2	0.4	0.4

Annexure VIp Village-wise bacterial population of *jeevamritha* samples collected from Andhra Pradesh

S. No.	Village Code	Bacteria (Log_{10}CFU ml^{-1})
1.	KNM	8.30
2.	KPL	8.00
3.	DPL	8.00
4.	VPM	8.30
5.	CDA	8.00
6.	JVM	8.00
7.	SKR	8.70
	Range (n=7)	8.00-8.70
	Mean	8.19
	SD	0.25

Annexure VII. Farming practices adopted by farmers selected for soil and plant analysis in Mandya district

Village	Farming type	Practices	Soil type
Paddy grower			
KK Halli	NF	GJM (0.5 t ha-1+JM (500 l ha-1/every 15-20 days intervals)	Black
	Non-NF	FYM (1 t ha-1)+Urea (125 kg ha-1)+DAP (50 kg ha-1)+ MOP (50 kg ha-1)	Black
Sugarcane grower			
Sollepur	NF	FYM (1 t ha-1)+JM (500 l ha-1)+ mulching with sugarcane trashes	Black
	Non-NF	FYM (1 t ha-1)+Urea (100 kg ha-1)+DAP (50 kg ha-1)+ mulching with sugarcane trashes	Black

Annexure VIIIa. Farming practices adopted by farmers selected for soil and plant analysis in Parbhani district

S. No.	Village code	Farming type	Practices	Soil type
Turmeric growers				
1.	KLN	NF	FYM (2 t ha^{-1})+JM (200 l ha^{-1} /30-40 days intervals+ One time drenching with a mixture of 250 gram sulphur + 10 litre cow urine ha^{-1}+*Neemastra* spray	Black
		Non-NF	FYM (2 t ha^{-1})+Urea (150 kg ha^{-1})+ DAP (100 kg ha^{-1})+ MOP (100 kg ha^{-1})	Black
2.	BGN	NF	FYM (4 t ha^{-1})+JM (300 l ha^{-1} /30-40 days intervals+ *Neemastra* spary	Black
		Non-NF	FYM (4 t ha^{-1})+ Urea (150 kg ha^{-1}) + DAP (100 kg ha^{-1})+ MOP (100 kg ha^{-1})	Black
3.	SPR	NF	FYM (2 t ha^{-1})+JM (200 l ha^{-1}/30-40 days intervals	Black
			FYM (3 t ha^{-1})+0.5 t vermicompost+ JM (100 l ha^{-1}) + *Beejamritha* (seed treatment)	
		Non-NF	FYM (2 t ha^{-1})+ Urea (175 kg ha^{-1}) + DAP (100 kg ha^{-1})+MOP (100 kg ha^{-1})	Black
			FYM (3 t ha^{-1})+Urea (200 kg ha^{-1})+DAP (100 kg ha^{-1})+ MOP (100 kg ha^{-1})	
Sorghum growers				
4.	KLN	NF	JM (100 l ha^{-1})+Two time drenching with a mixture of 250 gram sulphur + 10 litre cow urine ha^{-1}+*Beejamritha* (seed treatment)	Black
		Non-NF	Urea (100 kg ha^{-1}) +DAP (100 kg ha^{-1})+MOP (50 kg ha^{-1})	Black
5.	BGN	NF	FYM (1 t ha^{-1})+JM (100 l ha^{-1}/50 days intervals)+ *Beejamritha* (seed treatment)+*Neemastra* spray	Black
		Non-NF	Urea (100 kg ha^{-1})+DAP (75 kg ha^{-1})+MOP (50 kg ha^{-1})	Black
6.	SPR	NF	JM (500 l ha^{-1})/20-30 days intervals + *Beejamritha* (seed treatment)+ *Neemastra* spray	Black
		Non-NF	FYM (1 t ha^{-1})+ Urea (75 kg ha^{-1})+DAP (100 kg ha^{-1})+MOP (50 kg ha^{-1})	Black

JM=Jeevamritha; GJM=GhanJeevamritha; GM=Green manuring; FYM=Farmyard manure; DAP=Diammonium phosphate; MOP=Murate of potash

Name of Village: KLN=Kalgaon; BGN=Banegaon; SPR=Sonpuri

Annexure VIIIb. Farming practices adopted by farmers selected for soil and plant analysis in Hingoli district

S. No	Village code	Farming type	Practices	Soil type
Soybean growers				
1.	ARL	NF	FYM (1 t ha^{-1})+JM (200 l ha^{-1})+ *beejamritha* (seed treatment) + *Neemastra* spray	Black
2.		Non-NF	FYM 1 t ha^{-1}+ Urea (50 kg ha^{-1})+DAP (100 kg ha^{-1})+MOP (50 kg ha^{-1})+Sulphur (30 kg ha^{-1})	Black
3.	PSD	NF	FYM (1 t ha^{-1})+JM 300 l ha^{-1}/30 days intervals + *beejamritha* (seed treatment)	Black
4.		Non-NF	FYM 1 t ha^{-1}+ Urea (50 kg ha^{-1})+DAP (100 kg ha^{-1})+MOP (50 kg ha^{-1})+Sulphur (50 kg ha^{-1})	Black
5.	ANT	NF	Compost slurry (1 ha^{-1})+JM (300 l ha^{-1}/30 days intervals)+ *beejamritha* (seed treatment)+ *Neemastra* spray	Black
6.		Non-NF	FYM 1 t ha^{-1}+ Urea (50 kg ha^{-1})+DAP (100 kg ha^{-1})+MOP (50 kg ha^{-1})+Sulphur (50 kg ha^{-1})	Black
Turmeric growers				
7.	PSD	NF	FYM (8 t ha^{-1})+Seri waste (0.5 t ha^{-1})+JM (300 l ha^{-1}, two times)+*Neemastra* spray	Black
8.		Non-NF	FYM (6 t ha^{-1})+Urea (200 kg ha^{-1})+DAP (150 kg ha^{-1}+MOP (100 kg ha^{-1})	Black
9.	ANT	NF	FYM (6 t ha^{-1})+JM (300 l ha^{-1})_+*Beejamritha* (seed treatment)	Black
10.		Non-NF	FYM (5 t ha^{-1})+Urea (150 kg ha^{-1})+DAP (150 kg ha^{-1})+MOP (100 kg ha^{-1})	Black
11.	TLG	NF	FYM (2 t ha^{-1})+JM (200 l ha^{-1}/20 days interval) + *Neemastra* spray	Black
12.		Non-NF	FYM (2 t ha^{-1})+Urea (125 kg ha^{-1})+DAP (125 kg ha^{-1})+MOP (75 kg ha^{-1})	Black

Annexure IXa. Plot-wise availability of soil organic carbon (SOC) and major nutrients in turmeric and sorghum cultivated fields in Parbhani district

S. No	Village Code	SOC (%)		N (kg ha^{-1})		P (kg ha^{-1})		K (kg ha^{-1})	
		NF	Non-NF	NF	Non-NF	NF	Non-NF	NF	Non-NF
		Turmeric							
1	KLN	0.87	0.91	263	342	18.1	29.5	349	375
2	BGN	0.66	0.74	213	277	17.9	26.1	287	356
3	SPR	0.83	0.97	250	275	20.2	27.2	302	316
4	SPR	1.09	1.24	283	349	26.7	39.1	265	305
	Range (n=4)	0.66-1.09	0.74-1.24	213-283	275-349	17.9-26.7	26.1-39.1	265-349	305-375
	Mean	0.86	0.97	252	310	20.7	30.5	300	338
	SD	0.18	0.21	29.48	40.24	4.12	5.92	35.58	32.99
		Sorghum							
1	KLN	0.82	0.85	263	287	18.1	24.5	332	374
2	BGN	0.69	0.73	242	268	26.6	32.9	318	342
3	SPR	0.58	0.56	211	214	29.9	31.3	254	301
	Range (n=3)	0.58-0.82	0.56-0.85	211-263	214-287	18.1-29.9	24.5-32.9	254-332	301-374
	Mean	0.70	0.71	239	256	24.9	29.6	301	339
	SD	0.12	0.15	26.16	37.87	6.09	4.46	41.59	36.59

Annexure IXb. Plot-wise availability of secondary nutrients in turmeric and sorghum cultivated fields in Parbhani district

S. No	Village code	S (kg ha^{-1})		Ca (meq 100g^{-1})		Mg (meq 100g^{-1})	
		NF	Non-NF	NF	Non-NF	NF	Non-NF
		Turmeric					
1	KLN	26.1	29.4	19.6	21.4	5.9	6.1
2	BGN	23.4	27.5	16.4	18.1	4.8	5.6
3	SPR	34.1	36.7	15.4	17.4	5.6	6.9
4	SPR	28.6	27.9	22.1	24.5	8.1	8.6
Range (n=4)		23.4-34.1	27.5-36.7	15.4-22.1	17.4-24.5	4.8-8.1	5.6-8.6
	Mean	28.05	30.38	18.38	20.35	6.10	6.80
	SD	4.56	4.30	3.06	3.27	1.41	1.31
		Sorghum					
1	KLN	34.2	33.9	18.2	20.0	5.8	7.1
2	BGN	36.1	42.5	24.1	26.4	6.3	5.9
3	SPR	22.4	26.1	27.2	26.4	7.9	9.5
Range (n=3)		22.4-36.1	26.1-42.5	18.2-27.2	20-26.4	5.8-7.9	5.9-9.5
	Mean	30.90	34.17	23.17	24.27	6.67	7.50
	SD	7.42	8.20	4.57	3.70	1.10	1.83

Annexure IXc. Plot-wise availability of soil micronutrients in turmeric and sorghum cultivated fields in Parbhani district (Maharashtra)

S. No	Village code	Fe (mg kg-1)		Mn (mg kg-1)		Cu (mg kg-1)		Zn (mg kg-1)		B (mg kg-1)	
		NF	Non-NF	NF	Non-NF	NF	Non-NF	NF	Non-NF	NF	Non-NF
					Turmeric						
1	KLN	7.51	8.56	4.50	5.19	1.11	1.26	0.55	0.61	0.45	0.47
2	BGN	6.31	7.64	6.25	8.11	1.32	1.44	0.34	0.48	0.51	0.56
3	SPR	2.96	3.77	8.51	9.91	1.24	1.32	1.03	1.26	0.42	0.40
4	SPR	2.06	3.82	2.50	3.18	0.86	0.91	0.56	0.59	0.43	0.47
	Range (n=4)	2.06-7.51	3.77-8.56	2.5-8.51	3.18-9.91	0.86-1.32	0.91-1.44	0.34-1.03	0.48-1.26	0.42-0.51	0.40-0.56
	Mean	4.71	5.95	5.44	6.60	1.13	1.23	0.62	0.74	0.45	0.48
	SD	2.61	2.51	2.56	3.00	0.20	0.23	0.29	0.35	0.04	0.07
					Sorghum						
1	KLN	3.36	4.56	8.68	9.19	1.17	1.26	0.46	0.49	0.34	0.39
2	BGN	3.04	3.32	4.74	5.12	1.16	1.17	0.41	0.37	0.43	0.47
3	SPR	2.94	3.08	5.35	7.59	1.34	1.41	1.05	1.26	0.39	0.37
	Range (n=3)	2.94-3.36	3.08-4.56	4.74-8.68	5.12-9.19	1.16-1.34	1.17-1.41	0.41-1.05	0.37-1.26	0.34-0.43	0.37-0.47
	Mean	3.11	3.65	6.26	7.30	1.22	1.28	0.64	0.71	0.39	0.41
	SD	0.22	0.79	2.12	2.05	0.10	0.12	0.36	0.48	0.05	0.05

Annexure IXd. Plot-wise availability of soil organic carbon (SOC) and major nutrients in soybean and turmeric cultivated fields in Hingoli district

S. No	Village Code	SOC (%)		N (kg ha-1)		P (kg ha-1)		K (kg ha-1)	
		NF	Non-NF	NF	Non-NF	NF	Non-NF	NF	Non-NF
				Soybean					
1	KLN	0.76	0.91	238	250	25.2	28.9	502	533
2	PSD	0.73	0.77	225	262	21.3	29.7	299	316
3	PSD	0.64	0.72	262	269	17.8	20.5	204	222
	Range (n=3)	0.64-0.76	0.72-0.91	225-262	250-269	17.8-25.2	20.5-29.7	204-502	222-533
	Mean	0.71	0.80	241.67	260.33	21.43	26.37	335.00	357.00
	SD	0.06	0.10	18.77	9.61	3.70	5.10	152.23	159.50
				Turmeric					
1	PSD	0.94	1.16	274	293	23.2	32.9	311	356
2	ANT	0.83	0.98	266	302	19.7	28.9	267	289
3	TLN	0.86	1.02	243	298	24.8	35.8	264	296
	Range (n=3)	0.83-0.94	0.98-1.16	243-274	293-302	19.7-24.8	28.9-35.8	264-311	289-356
	Mean	0.88	1.05	261.00	297.67	22.57	32.53	280.67	313.67
	SD	0.06	0.09	16.09	4.51	2.61	3.46	26.31	36.83

Annexure IXe. Plot-wise availability of secondary nutrients in soybean and turmeric cultivated fields in Hingoli district (Maharashtra)

S. No.	Village Code	S (kg ha-1)		Ca (meq 100g-1)		Mg (meq 100g-1)	
		NF	Non-NF	NF	Non-NF	NF	Non-NF
Soybean							
1	KLN	26.2	27.1	15.1	16.6	4.1	4.8
2	PSD	28.2	26.9	26.2	28.7	6.0	6.9
3	PSD	35.6	39.1	19.3	18.4	4.8	3.7
Range (n=3)		26.2-35.6	26.9-39.1	15.1-26.2	16.6-28.7	4.1-6.0	3.7-6.9
	Mean	30.0	31.0	20.2	21.2	5.0	5.13
	SD	4.95	6.99	5.60	6.53	0.96	1.63
Turmeric							
1	PSD	31.2	31.8	23.0	24.9	4.5	5.1
2	ANT	22.1	21.5	24.1	26.6	5.2	5.9
3	TLN	19.6	23.3	21.8	25.0	4.8	5.7
Range (n=3)		19.6-31.2	21.5-31.8	21.8-24.1	24.9-26.6	4.5-5.2	5.1-5.9
	Mean	24.30	25.53	22.97	25.50	4.83	5.57
	SD	6.10	5.50	1.15	0.95	0.35	0.42

Annexure IXf. Plot-wise availability of soil micronutrients in soybean and turmeric cultivated fields in Hingoli district (Maharashtra)

S. No.	Village Code	Fe (mg kg-1)		Mn (mg kg-1)		Cu (mg kg-1)		Zn (mg kg-1)		B (mg kg-1)	
		NF	Non-NF	NF	Non-NF	NF	Non-NF	NF	Non-NF	NF	Non-NF
Soybean											
1	KLN	138	146	9.2	10.5	1.62	1.68	0.40	0.59	0.45	0.51
2	PSD	125	141	4.1	5.0	1.09	1.44	0.42	0.53	0.56	0.60
3	PSD	168	160	4.7	5.9	1.74	1.58	0.37	0.31	0.62	0.59
	Range (n=3)	2.15-2.74	2.52-3.47	4.1-9.2	5-10.5	1.09-1.74	1.44-1.68	0.37-0.42	0.31-0.59	0.45-0.62	0.51-0.60
	Mean	2.49	2.96	6.00	7.13	1.48	1.57	0.40	0.48	0.54	0.57
	SD	0.31	0.48	2.79	2.95	0.35	0.12	0.03	0.15	0.09	0.05
Turmeric											
1	PSD	15.39	16.5	10.4	11.6	3.26	3.12	1.58	1.45	0.72	0.69
2	ANT	9.8	11.1	6.6	5.9	1.65	2.12	1.02	1.16	0.56	0.67
3	TLN	2.94	2.46	2.2	3.1	0.88	1.27	0.91	1.01	0.61	0.68
	Range (n=3)	2.94-15.39	2.46-16.5	2.2-10.4	3.1-11.6	0.88-3.26	1.27-3.12	0.91-1.58	1.01-1.45	0.56-0.72	0.67-0.69
	Mean	9.38	10.02	6.40	6.87	1.93	2.17	1.17	1.21	0.63	0.68
	SD	6.24	7.08	4.10	4.33	1.21	0.93	0.36	0.22	0.08	0.01

Annexure IXg. Plot-wise soil microbial population in turmeric and sorghum cultivated fields in Parbhani district (Maharashtra)

S. No.	Village code	Bacteria (Log_{10} CFU g^{-1} soil)		Fungi (Log_{10} CFU g^{-1} soil)		Actinomycetes (Log_{10} CFU g^{-1} soil)	
		NF	Non-NF	NF	Non-NF	NF	Non-NF
				Turmeric			
1	KLN	8.30	8.40	3.65	4.31	3.30	3.40
2	BGN	9.00	9.64	3.60	3.78	3.30	3.85
3	SPR	8.18	8.30	3.00	3.48	3.00	3.18
4	SPR	8.88	8.95	3.54	4.04	3.54	3.65
Range (n=4)		8.18-9.00	8.30-9.64	3.00-3.65	3.48-4.31	3.00-3.54	3.18-3.85
	Mean	8.59	8.82	3.45	3.90	3.29	3.52
	SD	0.36	0.53	0.26	0.31	0.19	0.25
				Sorghum			
1	KLN	8.40	8.95	2.70	3.88	3.00	3.40
2	BGN	8.48	8.88	3.60	4.04	3.60	3.65
3	SPR	8.00	8.78	3.65	4.34	3.00	3.18
Range (n=3)		8.00-8.48	8.78-8.95	2.70-3.65	3.88-4.34	3.00-3.60	3.18-3.65
	Mean	8.29	8.87	3.32	4.09	3.20	3.41
	SD	0.21	0.07	0.44	0.19	0.28	0.19

Annexure IXh. Plot-wise soil microbial population in paddy cultivated fields turmeric and sorghum cultivated fields in Parbhani district (Maharashtra)

S. No.	Village Code	Free-living Nitrogen-fixing bacteria (Log_{10} CFU g^{-1} soil)		Phosphorus solubilizing bacteria (Log_{10} CFU g^{-1} soil)		*Pseudomonas* sp. (Log_{10} CFU g^{-1} soil)	
		NF	Non-NF	NF	Non-NF	NF	Non-NF
				Turmeric			
1	KLN	5.23	5.31	3.93	4.13	6.06	6.26
2	BGN	4.74	4.81	3.65	3.88	5.93	6.16
3	SPR	4.88	5.16	3.00	3.18	5.00	5.40
4	SPR	4.18	4.40	3.48	3.88	5.70	6.06
Range (n=4)		4.18-5.23	4.40-5.31	3.00-3.93	3.18-4.13	5.00-6.06	5.40-6.26
	Mean	4.76	4.92	3.51	3.76	5.67	5.97
	SD	0.38	0.35	0.34	0.36	0.41	0.34
				Sorghum			
1	KLN	4.30	4.54	3.40	3.18	5.00	5.88
2	BGN	4.30	4.48	3.78	4.24	5.65	6.15
3	SPR	4.18	5.34	3.65	3.78	4.70	5.18
Range (n=3)		4.18-4.30	4.48-5.34	3.40-3.78	3.18-4.24	4.70-5.65	5.18-6.15
	Mean	4.26	4.79	3.61	3.73	5.12	5.73
	SD	0.06	0.39	0.16	0.44	0.40	0.41

Annexure IXi. Plot-wise soil microbial population in soybean and turmeric cultivated fields in Hingoli district (Maharashtra)

S. No.	Village Code	Bacteria (Log_{10} CFU g^{-1} soil)		Fungi (Log_{10} CFU g^{-1} soil)		Actinomycetes (Log_{10} CFU g^{-1} soil)	
		NF	Non-NF	NF	Non-NF	NF	Non-NF
				Soybean			
1	KLN	7.70	8.00	3.18	3.30	3.81	4.15
2	PSD	8.40	8.88	3.30	3.40	3.65	3.54
3	PSD	8.00	8.48	3.00	3.40	3.18	3.88
Range (n=3)		7.70-8.40	8.00-8.88	3.00-3.30	3.30-3.40	3.18-3.65	3.54-4.15
	Mean	8.03	8.45	3.16	3.37	3.55	3.86
	SD	0.29	0.36	0.12	0.05	0.27	0.25
				Turmeric			
4	PSD	8.18	8.90	3.65	4.23	3.48	3.65
5	TLN	8.48	8.95	3.00	3.00	3.18	3.78
Range (n=2)		8.18-8.48	8.90-8.95	3.00-3.65	3.00-4.23	3.18-3.48	3.65-3.78
	Mean	8.33	8.93	3.33	3.62	3.33	3.72
	SD	0.15	0.03	0.33	0.62	0.15	0.06

Annexure IXj. Plot-wise soil microbial population in soybean and turmeric cultivated fields in Hingoli district (Maharashtra)

S. No.	Village Code	Free-living Nitrogen-fixing bacteria (Log_{10} CFU g^{-1} soil)		Phosphorus solubilizing bacteria (Log_{10} CFU g^{-1} soil)		*Pseudomonas* sp. (Log_{10} CFU g^{-1} soil)	
		NF	Non-NF	NF	Non-NF	NF	Non-NF
				Soybean			
1	KLN	4.40	4.18	3.18	3.40	5.18	5.30
2	PSD	4.18	4.54	3.40	3.70	5.40	5.90
3	PSD	4.85	4.88	3.48	3.78	5.48	5.65
Range (n=3)		4.18-4.85	4.18-4.88	3.18-3.48	3.40-3.78	5.18-5.48	5.30-5.90
	Mean	4.47	4.53	3.35	3.63	5.35	5.62
	SD	0.28	0.29	0.13	0.16	0.13	0.25
				Turmeric			
1	PSD	4.40	5.00	3.81	3.78	6.23	6.36
2	TLN	4.60	5.44	2.70	3.00	5.90	6.11
Range (n=2)		4.40-4.60	5.00-5.44	2.70-3.81	3.00-3.78	5.90-6.23	6.11-6.36
	Mean	4.50	5.22	3.26	3.39	6.07	6.24
	SD	0.10	0.22	0.56	0.39	0.16	0.12

Annexure IXk. Plot-wise plant nutrient contents in turmeric (above ground leaf) and sorghum (straw) macro-nutrient contents in Parbhani and Hingoli districts (Maharashtra)

S. No	Village Code	N (%)		P (%)		K (%)	
		NF	Non-NF	NF	Non-NF	NF	Non-NF
Turmeric							
1	KLN	0.94	1.02	0.31	0.36	1.39	1.48
2	SPR	0.92	0.98	0.29	0.32	1.01	1.04
3	TLN	0.88	0.87	0.33	0.31	1.18	1.23
4	PSD	0.95	1.04	0.36	0.39	0.96	1.05
5	ANT	0.84	0.96	0.28	0.27	1.15	1.21
Range (n=5)		0.84-0.95	0.87-1.04	0.28-0.36	0.27-0.39	0.96-1.39	1.04-1.48
	Mean	0.91	0.97	0.31	0.33	1.14	1.20
	SD	0.05	0.07	0.03	0.05	0.17	0.18
Sorghum							
1	BGN	0.81	0.84	0.29	0.28	1.14	1.16
2	KLN	1.05	1.10	0.34	0.36	1.01	1.12
3	SPR	1.08	1.11	0.31	0.35	1.09	1.08
Range (n=3)		0.81-1.08	0.84-1.11	0.29-0.34	0.28-0.36	1.01-1.14	1.08-1.16
	Mean	0.98	1.02	0.31	0.33	1.08	1.12
	SD	0.15	0.15	0.03	0.04	0.07	0.04

Annexure IXl. Plot-wise plant nutrient contents in turmeric (above ground leaf) and sorghum (straw) micro-nutrient contents in Parbhani and Hingoli districts (Maharashtra)

S. No	Village	Fe (mg kg^{-1})		Mn (mg kg^{-1})		Cu (mg kg^{-1})		Zn (mg kg^{-1})		B (mg kg^{-1})	
		NF	Non-NF	NF	Non-NF	NF	Non-NF	NF	Non-NF	NF	Non-NF
Turmeric											
1	KLN	165	200	74	87	5.2	5.8	29	27	14	18
2	SPR	155	178	97	92	6.1	5.7	31	35	18	17
3	TLN	141	153	109	101	6.8	7.4	25	28	19	24
4	PSD	197	189	98	111	5.6	5.9	21	24	21	25
5	ANT	178	194	125	139	4.8	5.3	28	36	19	26
Range (n=5)		141-197	153-200	74-125	87-139	4.8-6.8	5.3-7.4	21-31	24-36	14-21	17-26
	Mean	167.2	182.8	100.6	106.0	5.7	6.0	26.8	30.0	18.2	22.0
	SD	21.5	18.5	18.7	20.6	0.8	0.8	3.9	5.2	2.6	4.2
Sorghum											
1	BGN	130	148	69	75	6.1	6.9	32	30	17	19
2	KLN	157	154	84	81	5.6	5.4	41	44	21	18
3	SPR	167	179	76	85	7.4	7.9	29	35	22	28
	Range (n=3)	130-167	148-179	69-84	75-85	5.6-7.4	5.4-7.9	29-41	30-44	0.28-0.45	0.28-0.46
	Mean	151.3	160.3	76.3	80.3	6.4	6.7	34.0	36.3	20.0	21.7
	SD	19.1	16.4	7.5	5.0	0.9	1.3	6.2	7.1	2.6	5.5

Annexure IXm. Village-wise nutrient contents of *jeevamritha* samples collected from Maharashtra

S. No.	Village Code	OC (%)	N(%)	P (%)	K(%)	Ca (%)	Mg (%)	S (%)	Fe (mg l^{-1})	Zn (mg l^{-1})	Mn (mg l^{-1})	Cu (mg l^{-1})
1.	KLN	0.21	0.05	0.019	0.06	0.04	0.03	0.018	44.1	1.6	1.81	2.1
2.	SPR	0.19	0.06	0.021	0.05	traces	0.01	0.015	39.2	1.8	1.12	2.3
3.	TLN	0.24	0.04	0.018	0.04	0.05	0.03	0.014	38.9	1.3	1.84	1.9
	Range (n=3)	0.19-0.24	0.04-0.06	0.018-0.021	0.04-0.06	0.04-0.05	0.01-0.03	0.014-0.018	38.9-44.1	1.3-1.8	1.12-1.84	1.9-2.3
	Mean	0.21	0.05	0.02	0.05	0.045	0.023	0.016	40.73	1.57	1.59	2.10
	SD	0.03	0.01	0.00	0.01	0.01	0.01	0.00	2.92	0.25	0.41	0.20

Annexure IXn. Village-wise bacterial population of *jeevamritha* samples collected from Maharashtra

Sl. No.	Village Code	Bacteria (Log_{10}CFU ml^{-1})
1.	KLN	8.40
2.	SPR	8.30
3.	TLN	8.18
	Range (n=3)	8.18-8.40
	Mean	8.29
	SD	0.09

Annexure X. ANOVA result for yield comparison under different farming methods:

In order to compare the yield of crops under non-natural farming (NF), natural farming with FYM and natural farming without FYM, one-way ANOVA is used. The details are presented below:

1) Andhra Pradesh

i. Paddy

Yield(q/ha)

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Non-NF	60	50.86	20.42	2.64	45.58	56.13	15.00	111.11
NF without FYM	41	51.36	16.18	2.53	46.25	56.46	15.00	80.00
NF with FYM	77	53.79	15.18	1.73	50.35	57.24	23.58	106.25
Total	178	52.24	17.29	1.30	49.68	54.80	15.00	111.11

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	332.71	2	166.35	.554	.576
Within Groups	52586.21	175	300.49		
Total	52918.91	177			

The difference in yield among Non-NF, NF without FYM and NF with FYM in case of paddy in Andhra Pradesh could not be established (p=0.576)

ii. Sugarcane

Yield(t/ha)

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Non-NF	6	73.333	21.311	8.700	50.969	95.698	50.000	100.000
NF without FYM	3	55.557	17.346	10.015	12.467	98.646	41.670	75.000
NF with FYM	17	66.814	25.101	6.088	53.908	79.719	16.667	100.000
Total	26	67.019	23.313	4.572	57.603	76.436	16.667	100.000

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	634.10	2	317.05	.563	.577
Within Groups	12953.47	23	563.19		
Total	13587.57	25			

The difference in yield among Non-NF, NF without FYM and NF with FYM in case of sugarcane in Andhra Pradesh could not be established (p=0.577)

iii. Black gram

Yield(q/ha)

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Non-NF	11	5.40	3.96	1.19	2.74	8.06	1.25	11.67
NF without FYM	26	3.77	2.51	.49	2.75	4.78	.83	10.00
NF with FYM	8	6.40	3.18	1.12	3.75	9.06	.37	10.00
Total	45	4.64	3.15	.47	3.69	5.58	.37	11.67

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	50.95	2	25.48	2.778	.074
Within Groups	385.23	42	9.17		
Total	436.18	44			

Post Hoc Tests

Multiple Comparisons

Dependent Variable: Yield(q/ha)
Tukey HSD

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Non-NF	NF without FYM	1.63	1.09	.301	-1.01	4.28
	NF with FYM	-1.00	1.41	.759	-4.42	2.42
NF without FYM	Non-NF	-1.63	1.09	.301	-4.28	1.01
	NF with FYM	-2.63	1.22	.092	-5.61	.34
NF with FYM	Non-NF	1.00	1.41	.759	-2.42	4.42
	NF without FYM	2.63	1.22	.092	-.34	5.61

There was a statistically significant difference between groups (At $p < .1$) as determined by one-way ANOVA ($F(2,42) = 2.778$, $p = .074$). A Tukey post hoc test revealed that NF without FYM (M=3.77, S.D.=2.51, $p = 0.092$) has significantly lower yield than NF with FYM (M=6.4, S.D.=3.18). There was no statistically significant difference between Non-NF and NF without FYM as well as Non-NF and NF with FYM.

2) Karnataka

i. Paddy

Yield(q/ha)

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Non-NF	22	56.08	11.84	2.52	50.83	61.33	37.50	80.00
NF without FYM	16	38.78	9.38	2.35	33.78	43.78	20.00	50.00
NF with FYM	26	51.92	15.66	3.07	45.60	58.25	20.00	75.00
Total	64	50.07	14.54	1.82	46.43	53.70	20.00	80.00

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2924.66	2	1462.33	8.584	.001
Within Groups	10391.74	61	170.36		
Total	13316.40	63			

Post Hoc Tests

Multiple Comparisons

Dependent Variable: Yield(q/ha)
Tukey HSD

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Non-NF	NF without FYM	17.30*	4.29	.000	7.00	27.61
	NF with FYM	4.16	3.78	.518	-4.93	13.24
NF without FYM	Non-NF	-17.30*	4.29	.000	-27.61	-7.00
	NF with FYM	-13.15*	4.15	.007	-23.11	-3.18
NF with FYM	Non-NF	-4.16	3.78	.518	-13.24	4.93
	NF without FYM	13.15*	4.15	.007	3.18	23.11

*. The mean difference is significant at the 0.05 level.

There was a statistically significant difference between groups (At $p < .05$) as determined by one-way ANOVA ($F(2,61) = 8.584$, $p = .001$). A Tukey post hoc test revealed that NF without FYM (M=38.78, S.D.=9.38) has significantly lower yield than non-NF (M=56.08, S.D.=11.84, p <0.000) as well as NF with FYM (M=51.92, S.D.=15.66, p=0.007). There was no statistically significant difference between Non-NF and NF with FYM.

ii. Sugarcane

Yield(t/ha)

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	Upper Bound	Minimum	Maximum
Non-NF	15	99.94	33.36	8.61	81.47	118.42	50.00	150.00
NF without FYM	5	98.50	53.11	23.75	32.55	164.45	16.67	145.83
NF with FYM	22	104.55	29.73	6.34	91.36	117.73	50.00	156.25
Total	42	102.18	33.38	5.15	91.78	112.59	16.67	156.25

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	265.78	2	132.89	.114	.892
Within Groups	45426.87	39	1164.79		
Total	45692.64	41			

The difference in yield among Non-NF, NF without FYM and NF with FYM in case of sugarcane in Karnataka could not be established (p=0.892)

iii. Finger millet

Yield(q/ha)

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	Upper Bound	Minimum	Maximum
Non-NF	23	27.92	13.87	2.89	21.92	33.91	10.00	66.67
NF without FYM	8	36.09	11.64	4.11	26.36	45.82	11.25	50.00
NF with FYM	10	38.92	19.14	6.05	25.22	52.61	11.67	62.50
Total	41	32.20	15.39	2.40	27.34	37.05	10.00	66.67

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	994.41	2	497.20	2.229	.122
Within Groups	8477.48	38	223.09		
Total	9471.88	40			

The difference in yield among Non-NF, NF without FYM and NF with FYM in case of Finger millet in Karnataka could not be established (p=0.122)

iv. Banana

Yield(t/ha)

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Non-NF	2	3.44	2.21	1.56	-16.42	23.29	1.88	5.00
NF without FYM	4	2.65	1.13	.57	.85	4.45	1.43	4.17
NF with FYM	6	8.89	6.14	2.51	2.45	15.33	3.33	20.00
Total	12	5.90	5.27	1.52	2.55	9.25	1.43	20.00

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	108.01	2	54.00	2.465	.140
Within Groups	197.15	9	21.91		
Total	305.16	11			

The difference in yield among Non-NF, NF without FYM and NF with FYM in case of banana in Karnataka could not be established (p=0.140)

3) Maharashtra

i. Cotton

Yield(q/ha)

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Non-NF	35	17.02	7.94	1.34	14.30	19.75	5.00	33.33
NF without FYM	8	13.55	3.76	1.33	10.41	16.70	8.00	18.75
NF with FYM	9	14.58	5.48	1.83	10.37	18.80	8.75	25.00
Total	52	16.07	7.12	.99	14.08	18.05	5.00	33.33

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	102.45	2	51.23	1.010	.372
Within Groups	2484.88	49	50.71		
Total	2587.33	51			

The difference in yield among Non-NF, NF without FYM and NF with FYM in case of cotton in Maharashtra could not be established (p=0.372)

ii. Soyabean

Yield(t/ha)

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Non-NF	53	18.23	9.17	1.26	15.70	20.76	3.13	45.00
NF without FYM	33	17.97	6.05	1.05	15.83	20.12	6.67	35.00
NF with FYM	16	20.60	8.24	2.06	16.21	24.99	6.67	45.83
Total	102	18.52	8.11	.80	16.92	20.11	3.13	45.83

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	83.49	2	41.74	.630	.535
Within Groups	6563.85	99	66.30		
Total	6647.34	101			

The difference in yield among Non-NF, NF without FYM and NF with FYM in case of soyabean in Maharashtra could not be established (p=0.535)

iii. Jowar

Yield(t/ha)

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Non-NF	32	10.46	4.60	.81	8.80	12.12	2.50	21.25
NF without FYM	42	10.38	3.69	.57	9.23	11.53	3.13	15.00
NF with FYM	9	10.51	3.98	1.33	7.45	13.57	5.00	17.50
Total	83	10.42	4.05	.44	9.54	11.31	2.50	21.25

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.20	2	.10	.006	.994
Within Groups	1342.30	80	16.78		
Total	1342.51	82			

The difference in yield among Non-NF, NF without FYM and NF with FYM in case of jowar in Maharashtra could not be established (p=0.994)

iv. Turmeric

Yield(t/ha)

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	Upper Bound	Minimum	Maximum
Non-NF	19	40.03	10.71	2.46	34.87	45.19	20.00	62.50
NF without FYM	22	36.18	11.98	2.55	30.87	41.49	18.75	56.25
NF with FYM	39	38.68	6.62	1.06	36.53	40.82	25.00	53.75
Total	80	38.31	9.35	1.05	36.23	40.39	18.75	62.50

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	161.19	2	80.60	.921	.403
Within Groups	6741.33	77	87.55		
Total	6902.52	79			

v. Bengal gram

Yield(t/ha)

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	Upper Bound	Minimum	Maximum
Non-NF	20	16.79	10.16	2.27	12.03	21.54	4.06	43.75
NF without FYM	20	15.26	5.20	1.16	12.83	17.70	6.67	30.00
NF with FYM	2	15.63	6.19	4.38	-39.96	71.21	11.25	20.00
Total	42	16.00	7.87	1.21	13.55	18.46	4.06	43.75

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	23.59	2	11.80	.183	.833
Within Groups	2513.78	39	64.46		
Total	2537.37	41			

The difference in yield among Non-NF, NF without FYM and NF with FYM in case of turmeric in Maharashtra could not be established (p=0.833)

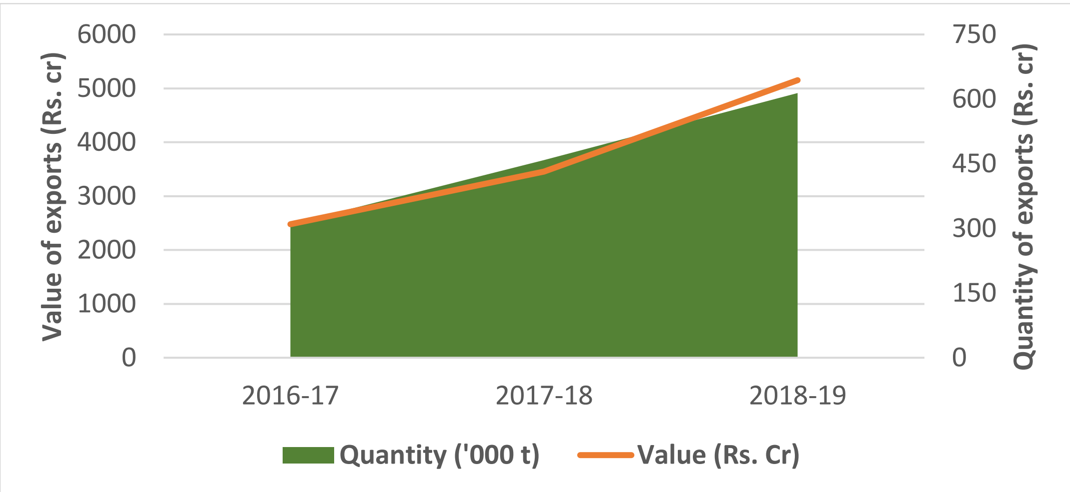
Annexure XI. Average yield of major crops in the selected states

Crop	Non-NF			NF					
				Without FYM			With FYM		
	Count	Yield (q/ha)	S.E.	Count	Yield (q/ha)	S.E.	Count	Yield (q/ha)	S.E.
Andhra Pradesh									
Paddy	60	50.86	2.64	41	51.36	2.53	77	53.79	1.73
Sugarcane*	6	73.33	8.70	3	55.56	10.01	17	66.81	6.09
Black gram	11	5.40	1.19	26	3.77	0.49	8	6.40	1.12
Karnataka									
Paddy	22	56.08	2.52	16	38.78	2.35	26	51.92	3.07
Sugarcane*	15	99.94	8.61	5	98.50	23.75	22	104.55	6.34
Finger millet	23	27.92	2.89	8	36.09	4.11	10	38.92	6.05
Banana*	2	3.44	1.56	4	2.65	0.57	6	8.89	2.51
Maharashtra									
Cotton	35	17.02	1.34	8	13.55	1.33	9	14.58	1.83
Soyabean	53	18.23	1.26	33	17.97	1.05	16	20.60	2.06
Jowar	32	10.46	0.81	42	10.38	0.57	9	10.51	1.33
Turmeric	19	40.03	2.46	22	36.18	2.55	39	38.68	1.06
Bengal gram	20	16.79	2.27	20	15.26	1.16	2	15.63	4.38

*yield in t/ha

(NF- Natural Farming, FYM- Farm Yard Manure)

Annexure XII. Export of organic products from India



Profile of Project Team

Principal Investigator	
	Dr. Ranjit Kumar is Head, Agribusiness Management Division at ICAR-NAARM. He has an experience of around 20 years. He has undertaken several research studies on technology adoption and marketing. His areas of interest include Rural/agricultural transformation, Producer Companies, Value chain analysis, Policy research, Risk management.
Co-Investigators	
	Dr. Sanjiv Kumar is Scientist (Agricultural Business Management) in the Division of Agribusiness Management at ICAR-NAARM. He has experience of more than 10 years. His areas of interest include Marketing Management, Agricultural Marketing, Value Chain Analysis, Data Visualization.
	Dr. BS Yashavanth is Scientist (Agricultural Statistics) in the Division of Information and Communication Management at ICAR-NAARM. He has experience of more than 4 years. His areas of interest include econometrics, time series analysis and forecasting.
	Dr. PC Meena is Principal Scientist (Agricultural Economics) in the Division of Agribusiness Management at ICAR-NAARM. He has an experience of around 15 years. His areas of interest include Agricultural Marketing and Price Policy, Supply Chain Management, Agricultural Input Marketing, Rural marketing, Contract Farming.
	Dr. AK Indoria is Scientist (Soil Physics and Soil Water Conservation) in the Division of Resource Management at ICAR-CRIDA. He has published more than 30 research articles in high impact journals.
	Dr. Sumantha Kundu is Scientist (Agronomy) in the Division of Resource Management at ICAR-CRIDA. He has experience of more than 7 years. His areas of interest include Conservation agriculture, Soil health management, Climate change, Carbon sequestration.
	Dr. M. Manjunath is Scientist (Agril. Microbiology) in the Division of Crop Sciences at ICAR-CRIDA. His research areas include Plant beneficial microorganisms, Plant microbe interactions.

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