A Farm-level Study on Natural Farming in Selected Areas of Jharkhand

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Executive Summary

India's agriculture has undergone a long history of intensification and extensification, particularly during the Green Revolution era. Unfortunately, this has led to negative environmental consequences and concerns about plateauing productivity in agriculture. In response, many alternative and sustainable farming methods have emerged worldwide. These farming approaches rely on local ecological processes, biodiversity, and cycles rather than external inputs. Zero-Budget Natural Farming (ZBNF) is India's version of alternative farming and has received support from civil societies, farmer movements, donor assistance, and state patronage. Recently, the government has given special attention to ZBNF and included it in the national organic farming program. However, there is a lack of scientific research on ZBNF compared to other sustainable farming approaches. It is crucial to gather sufficient scientific evidence to improve ZBNF systems and inform policy-making.

An initiative supported by donors was implemented to uphold the right to adequate food in African countries and India. This endeavour garnered backing from several nations and aimed to establish policies and legal provisions that align with the aforementioned objective. The Partnering Hope into Action (PHIA) Foundation collaborated with the Right to Food campaign in India to carry out this initiative, which primarily focused on policy advocacy. The ultimate aim was to bridge local-level efforts pertaining to food systems with national-level policies. While the project did not have a direct effect on farmers, it did centre on enhancing household food security in the Latehar and Khunti districts of Jharkhand. This was accomplished by giving priority to governance and NRM-based micro-planning in 40 different villages.

This Executive Summary pertains to a specific initiative, but it also draws on independent research conducted by the School of Agriculture and Rural Development at Ramakrishna Mission Vivekananda Educational and Research Institute (RKMVERI). We want to clarify that this is not a traditional impact assessment study due to some design issues. Instead, we ask readers and policymakers to view it as an independent research work focused on natural farming in Jharkhand. It provides valuable empirical insights into natural farming (NF) compared to conventional farming (CF) as practised by farmers.

The study analysed 151 farms in eight districts of Jharkhand state that have adopted natural farming in the past nine years. By comparing these farms to non-practising farms, the study examined farm characteristics, cropping choices, management practices, nutrient and labour use, and production economics. The study also evaluated soil physicochemical and microbial properties in select case study farms, as well as energy use and emission potential from predominant crops. Based on the evidence gathered from field research, the study proposes a systems model for natural farming.

Key Observations and Recommendations

- **Bringing stakeholders in natural farming together to co-create knowledge and utilize it effectively**

The definition of natural farming is often debated and normative, making it difficult to define and compare natural farms in practice. This challenge affects the epistemology of natural farming research and can lead to criticism. To address this, it is important to develop mutually agreed frameworks and parameters to assess the success of natural farming. These parameters need to be set through a series of consultations that draw on the perspectives of multiple stakeholders and respect the spirit of science. The shared meaning of these parameters is important to answer the practical question of why we are doing natural farming. Institutional collaboration is necessary to share resources and mainstream natural farming practices, research, and co-creation of knowledge for multiple stakeholders. The parameters must allow for functional means of assessment and avoid dependence on super-science unless critically needed.

- **Achieving precise targeting is necessary to establish the superiority of natural farming**

Not all smallholder farmers may benefit equally from NF. Favourable biophysical conditions, soil health, and access to irrigation are crucial factors for NF's success. Therefore, it is important to target NF projects at the regional and farm levels in an agroecological way to enhance their success. While it may seem exclusionary for certain locations, identifying niches is necessary for NF, especially during the early phases of experimentation and expansion. Once supportive ecosystems such as irrigation, institutional development, value-addition, and market integration are established, NF can expand to less favourable areas.

- **Focus on locating and selecting 'capable' farms**

In NF, both hired and family labour is utilized more often, likely for tasks such as composting, managing animal care, and creating liquid manure. Despite the imputed value of labour, the cost of labour is lower in NF due to the higher proportion of family labour involved. However, the availability of family labour is influenced by family size and type, as well as the migration of male members. To identify which smallholders are best suited to manage NF with the help of family labour, it is recommended that a farm typology be developed that considers factors such as land size and family demographics. This should be taken into account when developing the NF project.

- **Importance of the scale of operations and aggregations**

In many cases, empirical evidence may not show significant effects of NF on various system outcomes, such as system cost of cultivation, system gross revenue, system profitability, and productivity. However, it may reduce the cost of inputs, which may be offset by slightly higher labour costs and system yield. The benefits of NF become tangible and are reflected in an increase in farm economic parameters with an increased scale of operation. Therefore, it is necessary to scale up NF on the same farms (in addition to spreading to other areas) until the economic benefits for individual farmers are clearly established, even without any change in the macro environment (e.g., markets). The NF cycle for a region may start on homesteads or small plots (depending on available resources) and then expand to larger plots or clusters of plots (on the same field) until yield and economic advantages are demonstratively established. Before that, an out-scaling effort may not be sustainable due to supply-side failure, even after collectivization, which is contingent upon substantial social mobilization.

- **Monitoring soil health in natural farms**

It is crucial to monitor both nutrient management (such as fertilizer and organic input) and soil health parameters to sustain NF at the farm level. When a project confirms that an NF is being practised, the implementing agency must ensure that the practice of nutrient management is balanced. This is essential because some farmers may continue to use synthetic fertilizers, while others may apply unbalanced bulky manure.

Due to the significant heterogeneity of soil, even in the same landscape and farm, NF may have a different effect on soil health, and routine soil tests may not work across all farms. Evidence gathered in this research has not definitively established differences between the NF and non-NF in terms of soil physicochemical and biological counts, except for available Potassium. Organic Carbon, available Nitrogen, and Zinc were slightly higher in NF, whereas available Phosphorus, Copper, Iron, and Manganese were higher in CF. These small differences may exist when NF practices are not uniform and are in the initial stages at certain locations. Since biological fixation from the atmosphere is only possible for Nitrogen, NF could limit the supply of other nutrients. Thus, monitoring of major nutrient availability is required to avoid possible nutrient mining from NF plots.

Examining the enzymatic activities of microorganisms is recommended to identify the group of microorganisms responsible for increasing nutrient availability in the soil. While the microorganism count is only an indication of NF's positive impact on the soil, the study of enzymatic activity (in addition to microbial count) and screening microorganisms to identify novel consortiums are recommended for monitoring soil health in NF. This will require institutional collaboration between NF implementing agencies and specialized research institutions.

- **Gender concerns in natural farming initiatives**

When implementing NF programs, it is important to be cautious about relying too heavily on women's groups to avoid burdening farm women with unpaid work. This can create a dilemma between developing women's agency and managing unpaid workloads. It is important to recognize that many of the benefits of homestead plots may be controlled by farm women, and this same level of control should be extended to NF programs on larger plots of land that generate marketable surplus.

- **Ensuring the environmental and energy benefits of natural farming**

Natural farming offers significant environmental and energy benefits, primarily due to the decreased usage of synthetic fertilizers and fossil fuels in land preparation and irrigation. However, these advantages can be offset by management choices, such as manure application and yield/biomass production. To ensure sustainable land preparation and irrigation, natural farming practices should consider sustainable intensification methods, such as incorporating legumes into cropping systems. It is important not to prioritize yield and income over environmental sustainability, as industrial agriculture often does. Suitable technology, like solar power-driven irrigation and rationalized nutrient management, should be implemented in natural farming interventions. Monitoring the unsupervised application of organic manure is necessary to maintain these benefits. Crop choices, such as millets, pulses, and oilseeds, that are less resource-intensive should be considered for natural farming cropping systems. Multi-tier cropping or cropping systems that produce higher biomass sustainably can also help maintain system efficiency. Once the benefits of natural farming are established, accounting of ecosystem services can be used for policy advocacy and positive feedback for sustainable practices.

- **The importance of resource recycling techniques in natural farming practices**

In small farms, the interaction of resources plays a crucial role in achieving better outcomes, and circular mechanisms can be observed in many low external input systems. While natural farming may not necessarily promote resource recycling, it is essential to manage moisture and nutrients in a naturally maintained farm. Utilizing common property resources, fallow lands, and small livestock is critical to ensuring the sustainability of low external input natural farming systems. It is recommended that community-level institutions, such as farm schools, sustain appropriate science and technology interventions to revive common property resources and fallow lands for producing farm inputs such as fodder, biopesticides, biomass, and fuel. Encouraging evidence of agroforestry-assisted natural farming has emerged, and innovative models of bio-marts can also contribute to circularity in local agroecosystems.

- **Accounting for the ecosystem services of natural farming**

When promoting Natural Farming (NF) to policymakers, it is important to account for the ecosystem services it provides. However, this can be difficult and time-consuming due to the unique aspects of NF beyond just yield and income. The diverse inputs and farming practices make it challenging to objectively and factually assess the outcomes of NF. Conventional farming assessment practices may not apply, as accounting for locally managed biomass and labour engagement can be tricky. Additionally, non-standard measurement units and the lack of equivalent values for non-chemical inputs make it difficult to account for energy and emission. It is recommended that a framework be established for accounting ecosystem services in NF, which can be used to develop record-keeping journals for farmers. This will help link the demand and supply sides of NF and strengthen its promotion to policymakers.

- **A systems perspective for the natural farming projects**

In a region, the introduction and expansion of NF (natural farming) are influenced by various micro-level contexts, such as land holding, tenurial system, irrigation opportunities, livestock ownership, and availability of family labour. The aim of most NF interventions is to increase yield, profit, income diversity, biodiversity, energy efficiency, and reduce emissions, while also promoting food or nutrition security, health outcomes, climate resilience, and risk mitigation. These interventions can take the form of training, mass awareness, field schools, green colleges, common property resource management, fallow land management, and institution building in the form of cooperatives/producer organizations.

The outcomes of these interventions are manifested in the form of farmers’ individual and collective behavioural changes, resulting in the adoption of good practices, reduced synthetic fertilizer use, and increased organic manure applications. The management of inputs and labour, crop choice, and the decision to use fossil fuel in land preparation and irrigation affect the cost of cultivation, profitability, and energy efficiency, as well as soil fertility and crop yield. The success of these interventions also depends on a favourable policy environment that encourages producer-seller conglomerates to facilitate market access and price premiums, payment for ecosystem services, and risk management support.

Educational efforts, coupled with appropriate local institutions capable of promoting farmers' behavioural change, can create a large impact on the desired systems outcomes under NF. Thus, knowledge augmentation and behavioural change need to be warranted by field schools and green colleges. Practice level changes, especially the decision to irrigate and land preparation, can improve economic outcomes but reduce energy efficiency and emissions from the NF systems. The addition of institutions like farmer field schools and market access enhances profitability and other parameters also when management operations are energy efficient. This scenario is marginally improved with enhanced market access when reduced cost of cultivation and price premium is assured.

Conclusion

To successfully implement natural farming (NF) in smallholder systems, it's important to consider the diverse agroecological locations, irrigation coverage, cropping patterns, and socio-cultural and market orientations of farms. A typology delineation should be conducted, followed by a resource assay and constraint analysis, before initiating the NF project. The implementing agency can then work with farmers in a participatory farm design and on-farm experimentation process to develop location-specific NF models.

A Farm-level Study on Natural Farming in Selected Areas of Jharkhand

1. Introduction

Rising population and economic growth are causing increased and diverse demands for food in India, and agricultural production must match this demand without conceding environmental externalities. This is a huge challenge and an opportunity to sustain productivity in the long run. Agriculture supports the livelihoods of half of the rural population and forms the supply-side pillar of industries. Thus, sustaining farming communities and natural resources form the basis of India's prosperous agrarian societies and rural economies in India.

India's long history of agricultural intensification and extensification (the Green Revolution era) has resulted in serious environmental externalities on natural resources. As a response to these crises, in recent years, several alternative and sustainable farming approaches have emerged globally, including in India. Sustainable agriculture, organic farming, agroecological farming, ecological farming, and natural farming (NF) are some examples. All these farming practices rely on the ecological processes, biodiversity, and cycles adapted to local conditions, rather than the use of harmful agrochemicals. It combines traditional agricultural know-how with modern science and technologies that can arguably sustain the health of soil, environment, plant, and human. Instead of following a prescribed 'package' it maintains a living ecology on the farm and builds a fair relationship among all animate and inanimate entities involved. The concept of 'natural farming' came to prominence with the seminal works of Masanobu Fukuoka, a Japanese farmer and philosopher. However, the Indian version of NF, the Zero-Budget Natural Farming (ZBNF), stemmed from a distinct individual leadership with an ideal of neo-Gandhian autonomy. Unlike many alternative agriculture movements led by civil societies or farmer movements, ZBNF depended on farmer-led upscaling of the practice, which received donor assistance and state patronage in the course of time (Khadse & Rosset, 2019). Recently, the government of India has given special attention to NF and (very recently) made it a part of the national programme on organic farming. Unlike several sustainable farming approaches (especially agroecological farming) NF is less researched and oftentimes 'anecdotal'. Sufficient scientific evidence is needed to understand the science of NF for system improvement and informed policy-making.

Chemical-free nature-based farming practices are not a new concept in India and this has been practised here since time immemorial. Jharkhand is a state where a significant proportion of farming practices are by default organic in nature. The state was formed in the year 2000 by separating from Bihar mainly consisting of a large portion of the indigenous population. Jharkhand has a Scheduled Tribe population of about 26.3 per cent against an all-Indian average of 8 per cent, and a high percentage of area under forest cover (about 29 per cent against the Indian average of 23 per cent). Agriculture along with animal rearing is the primary occupation and there are three categories of the farming population in the state – (a) Indigenous farming communities – usually follow traditional farming practices by utilizing locally available organic/natural resources as agricultural inputs by utilizing their traditional knowledge; (b) Other resource-poor farmers – cannot afford high-input-intensive agriculture, use locally available resources as agricultural inputs, and seldom apply a very little amount of inorganic fertilizers; and (c) Resource-rich farmers – input-intensive conventional agricultural practices. The majority of the farming population follows agroecology-based farming practices in the state, and the large animal population in the state indicates the scope of agroecology based/natural/organic farming. Apart from this, Jharkhand has a large forest area under which different edible food materials, medicinal plants, mushrooms etc. are being gathered by the forest dwellers. These products are largely free from harmful chemicals and by default organic in nature. The total fertilizer consumption of the state is lesser than the national consumption (Table 1.1).

Table-1.1: Fertilizer consumption in Jharkhand and India

Place	Year	Fertilizer Consumption (kg/ha)		
		N	P	K
Jharkhand	2021	34.62	13.98	1.37
India 2017	2017	79.59	31.89	11.93

Source - https://www.ceicdata.com. Directorate of Economics and Statistics, Department of Agriculture and Farmers Welfare

The Government of Jharkhand formed a society 'Organic Farming Authority of Jharkhand' (OFAJ) in the year 2012 in order to capitalize on this default advantage and promote organic farming in the state.

Table-1.2: Different schemes under OFAJ to promote organic farming in Jharkhand

Sl. No.	Scheme	Districts	Area under organic farming (Ha)
1	PGS Certification Programme under PKVY	Ranchi, Ramgarh, Hazaribagh, Deoghar, Saraikela, Jamtara, Dumka, Sahebganj, Bokaro and Giridih	20,000
2	Swakshata Action Mission- Namami Gange	Sahebganj	540
3	NPOP Certification Programme	All 24 Districts	30,000

Source - OFAJ, 2018. http://www.organicjharkhand.in

The volume of popular debates and public consultation on 'natural farming' has not been matched by sound scientific publications to date. The specific meanings and 'ideological' inclination attached to NF demand evidence-based opinion and policy decisions. We see only a handful of publications in reputed bibliographic databases (the extracted database not given in the report) that have been reported in the last 10 years, almost half of which were produced in India for apparent reasons. Part of these review publications still deals with the ontological premise and emergence of 'natural farming' in India, while the recent publications address NF's economic impact and soil microbiological inquiry. However, a holistic empirical examination, including environmental externalities, is ruefully missing in the Indian context and there is no such publication available for the Jharkhand state. There are strong voices for natural farming within the government (Sitharaman, 2019), and ICAR-IIFSR, as a part of its Network Project on Organic Farming, has introduced coordinated pan-Indian on-farm trials on NF, whose detailed result is awaited.

There is another rationale for understanding the facts and dynamics of NF, especially in India. It is understandable that NF will probably struggle to replace external input-driven production to increase yields and attain economies of scale in densely populated regions. This is arguably a trap for millions of smallholders and their natural capital (Dorin, 2021). Despite the small and sporadically successful cases of NF adoption that have happened due to the advocacy of civil society networks and well-wishers in bureaucracy (Veluguri et al., 2021), there have been concerns about a counter-current of delegitimising the NF using the dominant discourse of reductionist and institutional agricultural sciences. Even if we consider this as a distant context for upscaling NF, science must unequivocally establish the novelty of NF from a non-reductionist and holistic perspective to generate evidence-based advocacy.

Donor-supported multi-country initiatives on NF were implemented in five African countries and India to create policy or legal provisions consistent with the realization of the right to adequate food. Partnering Hope into Action Foundation (Phia Foundation) implemented the Indian initiative jointly with the Right to Food campaign for policy advocacy. The concern was to systematically link local-level initiatives affecting food systems to policies adopted at national levels. There was no direct target for the farmers and the project focused on 40 villages of Latehar and Khunti district of Jharkhand, focusing more on governance and NRM-based micro-planning to improve household food security. Although the present study was not precisely an examination of the effects of the right-to-food campaign, but as a matter of fact, we studied the locations where the abovesaid interventions took place. That is why a comparative approach to this study (between natural and conventional farms) is apparent. But, due to several methodological – precisely design issues – we do not claim this to be a classical impact assessment study. The readers and policymakers are requested to take this as an independent research work on natural farming in Jharkhand, which demonstrates valuable empirical insights concerning natural farming (NF), juxtaposed with conventional farming (CF) as practised by the farmers.

In this study, we describe sampled farms in eight districts of Jharkhand state that started practising natural farming on their farms in the last nine years and compared them with the ‘conventional’ non-practising farms. Our examination consists of farm characteristics, cropping choices and management practices, nutrient and labour use, and production economics. We also assessed the soil physicochemical and microbial properties in selected case study farms and computed the selected crops' energy use and emission potential. This is followed by an examination of the resource recycling pattern of the case study farms to understand the central binding agents of the practising and non-practising farms. We closed our results by proposing a systems model for natural farming based on the evidence generated by our study.

1.1 Limitations of the Study

Every research study has its limitations because of the contextuality within which the research is carried out, which challenges the generalisability and external validity of the findings. The limitation of this current study goes beyond the problem of generalisation and involves the issues of scale (farm vs. food systems) and design (sampling, measurements, and controlling extraneous factors).

a) First, the ontological understanding of 'natural farming' is not supreme and there is diversity in the principles and practices of NF across stakeholder groups. We assume the 'endogeneity' of the farming system as a central guiding principle of NF and accept the practices promoted by the project implementing agencies as 'ideal' (i.e., the 'natural farm'). This implies that the report is more of an examination of the interventions undertaken by selected NGOs in Jharkhand that may not reflect exactly the examination of NF per se. This is important because the magnitude of impact on project farms may be different from the impact of NF practised on a 'model' or on-station farm.
b) We are very much aware of the food systems approach that could catapult and sustain NF in a region. Although NF is practised on individual farms, understandably, it may not reinforce NF's integration into regional agriculture (or food systems) unless the issue of landscape, community resources, markets, civil societies, institutions, and policy are taken care of. However, given the limited resources of the study, we focused on the farm-level measurements.
c) We collected soil samples and case study data from selected districts of the state (due to logistic constraints) and the non-coverage of certain districts in the case study and soil analysis may affect the study's external validity.
d) Although we assume that our dichotomization of natural and conventional farms is ideal and comparable, we are never sure whether an NF was truly practising the recommendations. During our field survey, we observed farms that are practising NF to varying extents and magnitude, which was difficult to verify and control by research designs.
e) A limitation of this evaluative study is the absence of an exhaustive baseline that aligns precisely with the present study's objectives (and, thus, the indicator set). A gold standard in experimental design is the difference-in-difference approach (comparing the natural and conventional farms in terms of 'net change happening before and after the practice of natural farming'), which could not be followed due to the absence of a precise baseline.
f) During the study, only a portion (often less than ~50 per cent) of the cultivable areas on individual farms were under NF, and it would be an overstatement to estimate outcomes (productivity, profitability, etc.) at the level of farming systems. As a result, the interpretation of an improved or deteriorated outcome due to the adoption of NF is never unquestionable.

g) The impact of NF is manifested in terms of a large number of parameters and many of them develop slowly over time. The initial year of NF varied across Jharkhand's districts, making the comparison of farms (in terms of changing parameters) difficult.
h) Study of complex socioecological systems (e.g., agroecosystems) asks for examining a plethora of farm-level indicators. In fact, plenty of such indicators are available today. However, indicators specific to NF are not unequivocally established. We have limited our description of NF to a handful of indicators covering socio-economics, farm management, input intensity, labour intensity, farm profits, energetics and GHG emissions. Moreover, there are difficulties in measuring many parameters in NF. For example, there is hardly any standardized equivalence of energy and emissions for many NF inputs, which needed to be indirectly estimated during computations.
i) Although we accounted for the organic inputs used by the farmers for several computations, we did not analyse the chemical compositions of the inputs prepared on the farm.
j) To address many of the above-mentioned confounding factors we matched the natural and conventional farms using propensity-score matching that matched the two groups of farms in terms of relevant covariates (e.g., farm size, locations, cropping systems, etc.). However, due to data insufficiency, the idea of the matching technique had to be dropped.

2. Research Methodology

In this section, we summarize the design aspects of the study along with the selection of study units (i.e., farms), data collection, and a suite of techniques employed to analyse them. We have described some of these approaches, methods and techniques in sufficient detail to enhance the reproducibility of the research. Also, we drew on relevant published research to rationalize our methodological choice to establish the objectivity of the study.

Operational definition of natural farming: In the present study, we do not adhere to a normative definition of NF and consider practising farms that followed the principles of endogeneity (managing resources from within) followed largely in natural, organic, and agroecology-based farming practices. These farms were selected from a theoretical population who have received training on natural farming, become part of community-based organizations, and were practising natural farming for the last nine years (the duration of different projects). We did not exclude the farms that reported a nominal use of fertilizers and pesticides in exceptional situations.

2.1 Study Locations

The study locations cover eight districts and 13 community development blocks of the Jharkhand and span all three agroclimatic zones of the state (Fig. 2.1). Case study sites covered four districts (Hazaribag, Ranchi, Latehar, Khunti) and we collected soil samples from three districts (Hazaribag, Khunti, Giridih) (Figs. 2.2a, 2.2b).

Literature suggests six types of soil in different parts of the state: a) Red soil (found in different parts of the state), b) Sandy soil (mostly found in the east Hazaribagh and Dhanbad region), c) Black soil (mostly found in the Rajmahal areas), d) Lateritic soil (mostly found in the highlands of Rajmahal, western Ranchi plateau and Pat region of south Palamu, and Dhalbhum area of Singbhum region), e) Red micaceous soil (mostly found in Koderma, Madu, and Jhumri-Tilaiya regions). Overall, in spite of great variation, the soil of Jharkhand has a poor water-holding capacity and is poor in organic contents.

The state's cultivated area is about 1.8 million ha, comprising 22% of the geographical area. Most of the cultivated area comes under rainfed conditions. The net irrigated area is about 0.16 million ha, constituting 9.3% of the cultivated area. The cropping intensity of the state is 126%. The major constraints of the state in agriculture are sloping lands with hard rock areas, severe soil erosion, water scarcity, acidic soils, low soil fertility, sub-optimal use of agricultural inputs, and open grazing in the rabi season. The major crops of the state are maize, rice, wheat and chickpea. However, paddy is grown mostly during the Kharif season. Different seasonal vegetables like cauliflower, cabbage, tomato, brinjal, radish, spinach, carrot, etc. are grown during the rabi season. The summer season is mostly kept fallow due to the unavailability of adequate irrigation water.

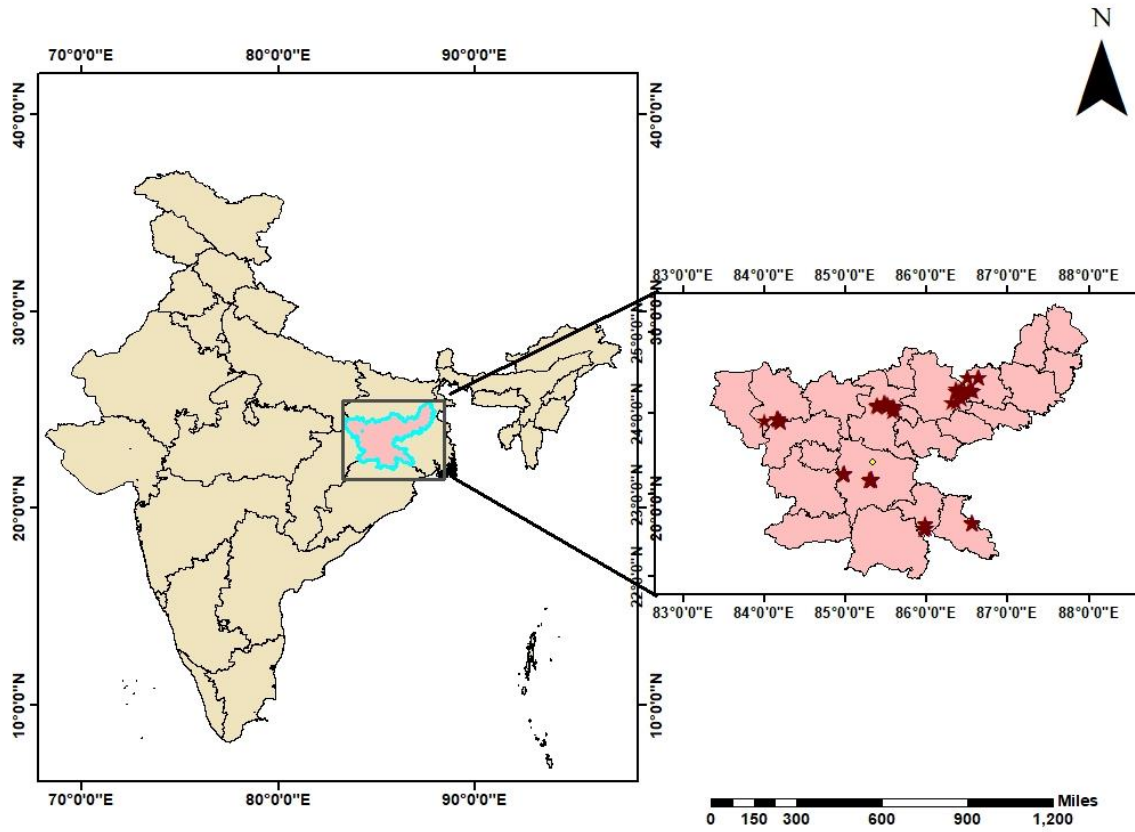


Fig. 2.1: Interviewed farms across eight districts of Jharkhand state

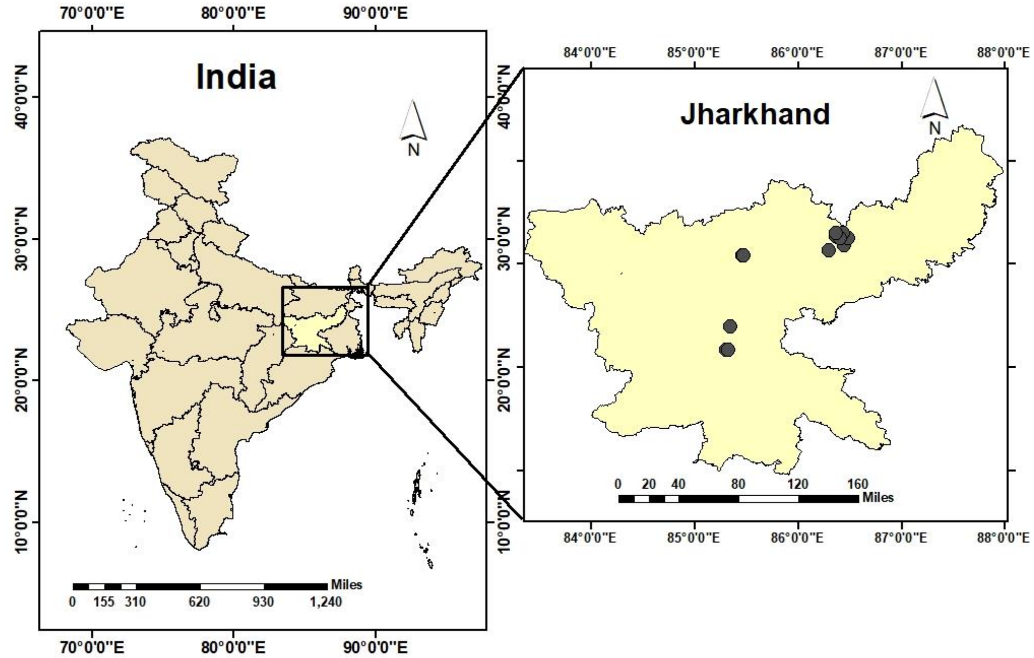


Fig. 2.2a: Locations of collected soil samples

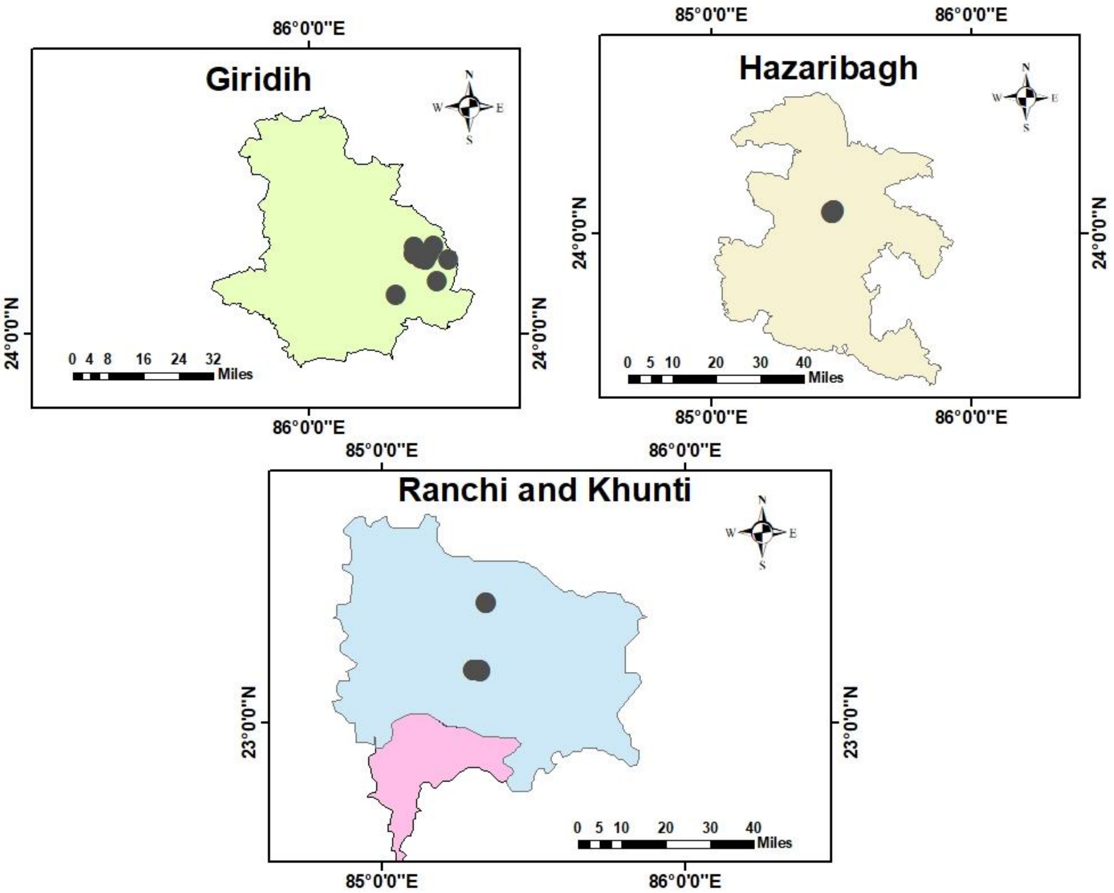


Fig. 2.2b: Locations of collected soil samples in three districts of Jharkhand

2.2 Sampling

Jharkhand comes under the Eastern Plateau and Hill Region (Agroclimatic Zone VII of India). However, the state has been divided further into Zone - IV (Central and North Eastern Plateau Zone), Zone V (Western Plateau Zone), and Zone VI (South Eastern Plateau). During the initial stakeholder consultations (online), we decided to collect data from all these three agroclimatic zones. Initially, we planned to draw samples (farms) in proportion to their actual distributions across the eight districts where NF was promoted by voluntary organizations as a part of an international initiative on natural farming. However, consultation with the representatives of concerned voluntary organizations (promoting NF) resulted in several adjustments to the actual sampling plan. The minimum agreed criteria were – a) the samples should cover all eight districts of the state, b) the sample size from individual districts will be commensurate to the total number of practising farms in the districts, c) nearly one-fourth of the farms will be 'non-practising' farms and at least 20% of the NF should be non-practising farms for all the districts, and d) the number stated above may vary depending on the presence and maturity of NF at the grassroots. Individual farm data collected from some districts had to be dropped during the database development because of their incompleteness and quality concerns. The implementing agencies provided the list of 'practising' and 'non-practising' farms from which samples were drawn purposively in consultation with the project personnel. Care was taken that samples are heterogeneous in terms of locations, biophysical conditions, and cropping systems. However, the logistic concerns, conditions of the farm, and farmer cooperations were taken into account in the field, especially for the case study farms, which needed prolonged surveys and farm inspections. Non-practising farms were selected from the same location (and community) with similar biophysical features (soil condition and irrigation provisions). The distribution of surveyed farms across districts is given in Table 2.1.

We utilised cross-sectional household survey data collected from eight districts of Jharkhand between April-July 2022. The research team made farm visits, hold discussions, conducted in-depth interviews with local stakeholders, and collected soil samples in November 2022.

Table 2.1: Sampling details followed in the household survey

	District	Implementing Organisation	Block	Practising Natural Farms	Non-Practising Farm	Total
Region-I	Deoghar	Avibyakti Foundation	Debipur, Madhupur	21	2	23
	Giridih	Avibyakti Foundation	Bengabad, Gande	20	3	23
	Hazaribagh	Srijan Foundation	Daru, Ichak, Tatijhariaya	16	5	21
	Ranchi	SPWD	Bero	10	9	19

Region-II	Khunti	NEEDS	Fuddi, Khunti	31	14	45
	Latehar	SPWD	Barwadih	17	5	22
Region-III	East Singbhum	CWS	Ghatsila	15	2	17
	Saraikela	CWS	Rajnagar	21	3	24
			TOTAL	151	43	194

2.3 Development of data collection instrument

We developed a standardized semi-structured interview schedule for collecting household and farm-level data. We drew on existing literature on sustainable agriculture supplemented with the inputs received in an online stakeholder consultation. This was followed by informal consultations with independent experts and persons associated with natural farming initiatives in Jharkhand. The draft instrument consisted of two parts – a) a farm-level survey for all the sampled farms; b) an elaborate survey for case study farms. The farm-level survey covered socio-economic and demographic information, farm assets, income-expenditure, cropping details, farm management – nutrient and labour, and farm economics. The case study part of the questionnaire covered input-output accounting of two major crops per farm, recording best practices, and a farm resource interaction matrix. The draft instrument was pre-tested on 15 non-sampled farms near the Ranchi district before finalizing the instrument.

2.4 Data collection

We trained field enumerators several times before and during data collection. The enumerators stayed in the communities and collected field data using the standardised interview schedule in face-to-face conditions (April-May 2022) after securing informed consent from the respondents. All interviews were followed by farm visits and observations. On average, enumerators needed 90 minutes and 150 minutes to complete interviews for a non-case study and case study farm, respectively. In-depth interviews and farm visits by the core research team (November 2022) happened in the fields with individual farmers and (sometimes with) a group of farmers.

We collected a total of 36 composite surface soil samples (0–15 cm) from as many plots in November 2022. Each composite sample was a mixture of three subsamples from each plot. For microbial analysis, we excavated three plants randomly in each plot and collected rhizospheric soil from each of them to form a composite sample.

2.5 Data Analysis

2.5.1 Impact Assessment

We employed a quasi-experimental design to examine the effect of natural farming on a set of outcomes from the farms (Cost of Cultivation, Labour use intensity, Paddy yield, and System Profitability). Due to the small size of the non-practising farms in our sample, we could not claim the validity of the propensity score matching (PSM) and Coarsened Exact Matching (CEM) approaches. The endogenous switching regression (ESR) model could not be used due to a small number of covariates, as a result of which convergence was not achieved even after around 10000 iterations. As an alternative, we tried the instrument variable model by the two-stage least squares (2sls) technique assuming tropical livestock unit (TLU) as an instrument variable (hypothesized that it may affect participation in natural farming but not the outcome from crop farming). But the 2SLS results showed that TLU was a weak instrument in the data set (failed the Durbin chi-square and Wu-Hausman test). Therefore, we went for an instrument variable modelling with a limited information maximum likelihood (LIML) technique. LIML examined the treatment effect along with the factors influencing several outcomes in practising natural farms, namely – System profitability (INR/ha), System Cost of Cultivation (INR/ha), Labour use intensity (person days/ha), and Paddy Yield (Kg/ha).

2.5.2 Soil Analysis – Physicochemical

The composite samples were air-dried, ground, and passed through a 0.2 mm sieve. Soils were analyzed for saturated paste pH using a pH meter (Jackson, 1967), salinity using a conductivity electrode (Jackson, 1967), mineralizable organic carbon (modified Walkley and Black, 1934), available K_2O (Jackson, 1967), available P (Olsen et al., 1954), available N (Subbiah and Asija, 1956), available Zn, available Cu, available Fe, and available Mn (DTPA-extractable content determined by Atomic Absorption Spectrophotometer (Lindsey and Norvell, 1978). We stored composite samples in sealed plastic bags before refrigeration (at 4^oC). Each sample was divided into two parts– a) air-drying before physicochemical analysis, and b) refrigeration before soil microbial analysis.

2.5.3 Soil Analysis – Microbial

To determine the microbial population, we serially diluted the soil solution at a desired concentration and plated it with three replications on appropriate culture media. For bacterial population, plates were incubated at 37^oC overnight while for actinomycetes plates were incubated at 37^oC for one-two day. For the fungal population, plates were incubated at 30^oC for two days. After incubation, colonies were counted following standard microbiological norms. Study protocol for analysis of N, P, and K solubilising bacteria and antibiotic-resistant bacteria has not been incorporated in the report to avoid technical intricacies. They may be shared in the form of an independent publication.

2.5.4 Energetics computation

We estimated the energy budget of the cropping systems accounting for the number of recorded inputs such as land preparation, sowing/transplanting, irrigation, manuring/fertilization, weeding, pesticide, harvesting, and post-harvest operations. We computed the output energy based on the economic yields in a cropping system. Energy equivalents for each input and output, multiplied by their number/amount, resulted in the estimated energy use for a cropping system.

The following energy indices were calculated as per equations 3 to 7 by Ray et al. (2020b):

$$\text{Specific energy (MJ/kg)} = \frac{\text{Energy input (MJ/ha)}}{\text{Maize output (kg/ha)}} \quad (1)$$

$$\text{Energy productivity (kg/MJ)} = \frac{\text{Maize grain yield (kg/ha)}}{\text{Energy input (MJ/ha)}} \quad (2)$$

$$\text{Net energy gain (MJ/ha)} = (\text{Energy output} - \text{energy input}) \quad (3)$$

$$\text{Energy ratio} = \frac{\text{Energy output (MJ/ha)}}{\text{Energy input (MJ/ha)}} \quad (4)$$

2.5.5 Emission computations

We used the IPCC Fifth Assessment Report (IPCC, 2014) to estimate GHGs emissions, Equivalents of emissions for crop management inputs such as machinery, fuel, electricity, fertilizer, manure and pesticide applications in a cropping system were used to estimate GHG emissions from a cropping system. We converted the estimated emission from different cropping systems (kg/ha) into tCO_2eq/ha (global warming potential (GWP), Eq. 5). The GWPs of CO_2, in a 100-year time horizon, were considered as 1 as per the IPCC Fifth Assessment Report (IPCC, 2014). This value was then converted to yield-scaled GHG (YSGHG) emission by using Eq. 6 (Li et al., 2015):

GWP ($tCO_{2eq}ha^{-1}year^{-1}$) = CO_2 emission X GWPofCO_2 + CH_4 emission X GWPofCH_4 + N_2O emission X GWPofN_2O [5]
[summated for all crops in a system]

Yield scaled GHG emission of a system (tCO_{2eq} t^{-1} of system yield) =
GWP (tCO_{2eq} $ha^{-1}yr^{-1}$)/System yield (t $ha^{-1}yr^{-1}$) [6]
[summated for all crops in a system]

2.5.6 Farm economics

Based on farmers' self-reporting, we computed the system cost of cultivation, system gross return (revenue) and system net return (profit) for different cropping systems. The system cost of cultivation (INR/ha) was the sum of costs incurred for performing field operations (sowing to harvesting, threshing and storage of seeds) and purchasing inputs for all crops in a cropping system. We used the Cost A1 concept as proposed by the Commission for Agricultural Costs and Prices (CACP) using the prevailing market prices of inputs and outputs (for the year 2021). System gross return was the summation of products of a crop's economic output and corresponding (prevailing) market prices.

Gross return (INR ha^{-1} yr^{-1}) = Systems output (Kg ha^{-1} yr^{-1}) X Output price (INR Kg^{-1}) [summated for all the crops in a cropping system] [7]

Net return (INR ha^{-1} yr^{-1}) = Gross return (INR ha^{-1} yr^{-1}) – Cost of Cultivation (INR ha^{-1} yr^{-1}) [8]

2.5.7 Resource interaction network analysis

We identified 14 types of distinct resources/farm components, namely Paddy Fields, Vegetable Fields, Cattle, Goats, Pigs, Poultry, Well, Trees, Kitchens, Homesteads, Common Property Resources (CPR), Fallow, Canals, and Manure Pits. A 14x14 table was incorporated into the interview schedule (for the case study farms) to collect resource interaction data. We considered the presence of a resource interaction (RI) on the farm when a perceived flow of energy or matter or sharing of space between any two of these 14 resources existed. Field enumerators checked on the existence of such interactions in consultation with the respondents and farm visits. We recorded the RI in a 14x14 binary matrix for all 15 case study farms (10 NFs and 5 CFs). Then, the RI networks of NF and CF were aggregated separately to develop a group RI network for natural and conventional case study farms. In graph-theoretic parlance, a node in the RI network represents a resource/farm component, and a directed tie represents the interaction between two nodes. Based on the matrices, we generated two types of network information for the group RI networks: First, the network properties namely average degree, degree centralization, density, component ratio, connectedness, fragmentation, transitivity/closure, and mutuals, to understand the nature of resource interaction in the farms (Borgatti et al., 2018). Second, we examined the triad abundance (all possible combinations involving three farm components) in group RI networks of NFs and CFs. We used UCINET for Windows software (Borgatti, Everett, & Freeman, 2002) for matrix manipulation and analyses of the farm RI's structural composition, and computation of network properties of RI. Network visualizations were created using NetDraw software (Borgatti, 2002).

2.5.8 Statistical Analysis and Software Used

A list of statistical techniques and software is given in Table 2.2.

Table 2.2: Statistical techniques and software used in the study

Objective	Statistical technique	Software used
Comparison of farms and farmers (socio-economic, demographic, farm management, farm economics, soil properties, energetics, emission)	Descriptive and inferential statistics	SPSS 25.0 for Windows
Effect of Natural Farming on a set of system outcomes	Instrument Variable modelling with a limited information maximum likelihood (LIML) technique	STATA 14.0
Farm Resource Interaction study	Graph-Theoretic Approach	UCINET and NetDraw

3. Results

3.1 General description of the sample

The sampled farms were mostly middle-aged, with nearly ~80% in the age group of 30-60 (Table 3.1). More than four-fifth of the farms were male-headed and were the family's primary earners. Nearly one-third of the population attended higher secondary schools. The majority of the farms are operated by tribal people and people from backward castes. The majority of farmers belonged to large families (~70% above 5) and NF farmers were more experienced in farming than the CFs. The majority of the markets and metalled roads existed within a 5 Km distance from the farms.

Table 3.1: Background information on the practising natural farmers and conventional farmers

		Practising Natural Farmers	Conventional Farmers
Age			
	<30 years	5 (3.33)	6 (13.95)
	31-45 years	73 (48.67)	15 (34.88)
	46-60 years	64 (42.67)	18 (41.86)
	>60 years	8 (5.33)	4 (9.30)
Sex			
	Male	124 (82.1)	36 (83.7)
	Female	27 (17.9)	7 (16.3)
Sex of the primary earner			
	Male	122 (81.79)	30 (69.77)
	Female	29 (19.21)	13 (30.23)
Education of the principal earner			
	No formal education	47 (31.13)	20 (46.51)
	Primary	51 (33.77)	4 (9.30)
	Secondary	44 (29.14)	13 (30.23)
	Above secondary	9 (5.96)	6 (13.95)
Occupation of the principal earner			
	Farming	145 (96.03)	36 (83.72)
	Others	6 (3.97)	7 (16.28)
Caste			
	Scheduled Tribe	89 (58.9)	27 (62.8)
	Schedules Caste	4 (2.6)	1 (2.3)
	Other Backward Caste	51 (33.8)	14 (32.6)
	Forward Caste	7 (4.6)	1 (2.3)
Family Size			
	<5	45 (29.80)	11 (25.58)
	5-7	86 (56.95)	27 (62.79)

	>7	20 (13.25)	5 (11.63)
Farming Experience			
	<10 years	6 (3.97)	6 (13.95)
	10-20 years	57 (37.74)	19 (44.19)
	21-30 years	66 (43.71)	12 (27.91)
	> 30 years	22 (14.57)	6 (13.95)
Distance from Market			
	Within 1 km	8 (5.67)	1 (2.44)
	1-5 km	90 (63.83)	24 (58.54)
	5-10 km	28 (19.86)	15 (36.58)
	More than 5 km	15 (10.64)	1 (2.44)
Distance from metal road			
	Within 1 km	75 (50.0)	28 (65.12)
	1-5 km	65 (43.33)	15 (34.88)
	More than 5 km	10 (6.67)	0 (0.0)

The CF had higher homestead size and perceived soil fertility than the NF, but the NF had higher irrigation coverage and a higher mean value (non-significant) for owned land and cultivated land (Table 3.2). Except for goat kids, the livestock holding was not significantly different between NF and CF. Pieces of the land parcel (3-4) is inconvenient for management, especially for NF which needed intense monitoring for beginners. More than three cattle on average were helpful for sourcing cow dung manure, a prerequisite to maintaining the principles of natural farming.

Table 3.2: Assets owned by the practising natural farms and conventional farms

	Unit	N	Practising Natural Farms Mean (St. Error)	N	Conventional Farms Mean (St. Error)	t-sig.
Land parcels	Number	148	3.73 (0.30)	37	3.32 (0.32)	0.515
Owned land	Decimal	151	289.09 (29.96)	43	252.07 (54.02)	0.558
Homestead land	Decimal	133	28.79 (2.06)	28	47.54 (11.98)	**0.009**
Cultivated land	Decimal	151	254.17 (29.57)	43	215.07 (45.67)	0.519
Total irrigated area	Decimal	149	163.47 (19.28)	37	99.65 (21.07)	0.114
Irrigation coverage	%	149	54.77 (2.58)	37	41.08 (5.04)	**0.018**
Perceived soil fertility	1-5 scale	151	2.19 (0.53)	42	2.67 (0.53)	**0.000**

Table 3.3: Livestock ownership by the practising natural farms and conventional farms

	Unit	N	Practising Natural Farms Mean (St. Error)	N	Conventional Farms Mean (St. Error)	t-sig.
Cattle adult	Number	111	3.20 (0.21)	29	3.31 (0.46)	0.814
Cattle kid	Number	44	2.39 (0.24)	11	1.82 (0.23)	0.256
Goat adult	Number	89	6.85 (0.58)	23	4.96 (0.83)	0.123

Goat kid	Number	54	4.17 (0.53)	14	2.14 (0.35)	**0.002**
Poultry adult	Number	80	12.99 (1.56)	17	9.71 (3.23)	0.373
Poultry chick	Number	33	9.52 (1.25)	11	7.73 (1.83)	0.463
Tropical Livestock Unit*	Composite index	151	3.48 (0.23)	43	2.89 (0.45)	0.239

* Computed following Storck et al. (1991)

3.2 Effect of natural farming

We observed a significant difference only in the system input cost and not in terms of other economic parameters (Table 3.4). The difference in input cost may be attributed to the reduced cost of fertilizer. However, revenue and profit are dependent on yield increment and market price. Due to a marginal dip in production and the absence of a price premium, we could not trace a significant difference in revenue or profitability. Many NF plots harboured diverse crops, but they were largely on the homesteads and for household consumption.

Table 3.4: Economics of natural and conventional farms

	Unit	N	Practising Natural Farms Mean (SE)	N	Conventional Farms Mean (SE)	t-sig.
System input cost	INR/ha	124	7917.37 (668.24)	39	12369.96 (2665.12)	**0.021**
System cost of cultivation	INR/ha	149	22723.57 (2077.96)	43	31120 .06 (5415.76)	0.153
System revenue	INR/ha	148	147179 (32379)	41	148599 (33123)	0.982
System Profit	INR/ha	146	74430.36 (12629.47)	39	88458.19 (24107.04)	0.610
Paddy Yield	Kg/ha	146	3073.59 (103.97)	41	3400.99 (184.76)	0.137

3.2.1 The effect of NF – econometric evaluation

As we mentioned earlier, this study was not in a precise sense an impact assessment for apparent reasons. The confounding effect of a large number of factors might challenge establishing the causality of NF on crop yield, cost of cultivation, farm income and farm profitability. Still, we employed a quasi-experimental design to examine the effect of natural farming on crop productivity and profitability using the propensity score method (PSM). PSM enabled the comparison of NF and CF with similar values on the propensity score, and possibly other covariates (e.g., landholding, irrigation coverage, livestock ownership, among others). In this study, the propensity score of the farmers practising natural farming was generated using a logit model, followed by the use of nearest neighbour matching methods. We used the matched sample to compute the average effect of natural farming on selected outcome variables namely – system cost of cultivation (INR/ha), system gross revenue (INR/ha), system profitability (INR/ha), and paddy yield (Kg/ha).

However, due to the small size of the non-practising group, we decided to claim the validity of the PSM findings. The same observation applies to dropping the Coarsened Exact Matching (CEM) results. We also tried the endogenous switching regression (ESR) model, but due to the small number of covariates, convergence was not achieved even after around 10000 iterations. As an alternative, we tried the instrument variable model by the two-stage least squares (2sls) technique. We assumed tropical livestock unit (TLU) as an instrument variable (hypothesized that it may affect participation in natural farming but not the outcome from crop farming). But the 2SLS technique shows that TLU is a weak instrument in the data set (it failed the Durbin chi-square and Wu-Hausman test). Therefore, we went for an instrument variable modelling with a limited information maximum likelihood (LIML) technique. LIML examined the treatment effect along with the factors influencing several outcomes in practising natural farms, namely – System profitability (INR/ha), System Cost of Cultivation (INR/ha), Labour use intensity (person days/ha), and Paddy Yield (Kg/ha).

It was clearly shown that **NF did not have any significant impact on any system outcomes** (Table 3.5). (log of) Landholding (p=.000) significantly explained the cost of cultivation, labour use, and paddy yield in the farming systems. Family size ($p=.001$) influenced the cost of cultivation, and irrigation influenced labour use and paddy yield in the study areas. These observations are in line with existing literature and since we are only interested in the treatment effect (NF's influence on system outcomes), we do not discuss these observations. The non-significant treatment effect of NF is not surprising for several reasons – first, the sampled CFs were still using moderate input intensity, thus the adoption of NF manifested marginal changes in terms of cost of cultivation and system profitability. Also, a proportion of NF still used a moderate amount of synthetic inputs resulting in less difference in terms of cost of cultivation. Even the simple inferential statistics (Table 3.4), without matching for covariates, could not find significant differences between the cost of cultivation and system profitability. Second, most of the farms adopted NF on a small proportion of their cultivated land (often on homestead plots), which could hardly impact the system outcomes. Third, smaller plots of CF meant small changes in labour requirements (for preparing liquid manures, composting, etc. Also, when NF was confined to homesteads, we apprehend that the recording of labour requirements was very difficult. Fourth, the productivity of paddy was reduced slightly because of the factors already mentioned above – a low-input system in both NF and CF and a proportion of NF using synthetic fertilizers. However, accounting for the local bio-physical and varietal choices were not accounted for in the analysis and it is difficult to definitively estimate the actual yield difference in the farmers' field.

Table 3.5: Treatment effect regression of system outcomes, maximum likelihood (N=194)

	System Profitability		Cost of Cultivation		Labour use intensity		Paddy yield	
	Coefficient	*p*-value	Coefficient	*p*-value	Coefficient	*p*-value	Coefficient	*p*-value
NF (Tr)	-0.029	0.986	0.428	0.657	-0.440	0.693	0.542	0.499
log age	0.215	0.700	0.183	0.541	-0.354	0.306	-0.085	0.733
log land	-0.057	0.738	-0.490	**0.000**	-0.347	**0.004**	-0.163	**0.061**
caste	-0.033	0.776	-0.030	0.647	0.038	0.617	0.044	0.420
sex	-0.302	0.330	-0.139	0.423	0.094	0.640	-0.127	0.380
family size	0.084	0.123	0.094	**0.001**	0.015	0.647	0.016	0.500
irrigation	-0.002	0.687	-0.022	0.304	0.011	**0.000**	-0.033	**0.066**
constant	9.801	.000	11.005	0.000	7.699	0.000	8.677	0.000
	Wald chi-square – 5.33		Wald chi-square – 66.97		Wald chi-square – 47.33		Wald chi-square – 9.71	
	0.0262		0.2368		0.1340		-	

3.3 Management of natural farming and conventional farming

The management of farming has been addressed under three major heads – nutrient management, labour management, and application of good practices for sustainable farming. Unexpectedly, the percentage of NF farmers applying Urea and DAP is still 37.09% and 47.68%, respectively (Table 3.6). However, this percentage was smaller than the CFs. Also, the % of NF farmers applied vermicompost more than the CFs. Neglecting the minuscule proportion of farmers applying phosphatic and potassic fertilizers, we observe NF has applied less amount of urea (13.83%) and DAP (43.14%), and higher cow dung manure (16.80%) and vermicompost (73.87%) on average. The difference between NFs and CFs in terms of DAP application was statistically significant. However, the interpretation will hold true for the practising NF, who 'surreptitiously' applied fertilizers in their field. They apply N and P doses (Urea and DAP taken together) typical of the Jharkhand state (N:P:K is 34.62:13.98:1.37). Hence, the important observation lies in the higher proportion of non-fertilizer users and low average dose of fertilizer among the NF farmers. Nevertheless, the use of fertilizers is antithetical to the spirit of natural farming (Smith et al., 2020) despite pragmatic views concerning integrated nutrient management. A 'crude estimation' suggests that Jharkhand consumed 2.52 Lt urea and 0.58 Lt phosphatic fertilizers in 2020-21. A 13.83% reduction in urea use means a 34851 t reduction in urea application, which can alone save 34.96 crore subsidy on the nutrient-based subsidy schemes. Similarly, a 43.14% reduction in phosphatic fertilizers could save nearly 34.16 crores in subsidy (considering subsidy specifications for the period 20.05.2021 to 31.03.2022, which has been increased further).

3.6 Nutrient use by the practising natural farms and conventional farms

	Practising Natural Farms in Kg/ha [Mean (SE of mean)]	% of farms used last year*	Conventional Farms in Kg/ha [Mean (SE of mean)]	% of farms used last year*	t-sig
Urea	36.13 (6.04)	37.09	41.93 (6.99)	67.44	0.628
DAP	32.91 (5.39)	47.68	57.88 (8.08)	86.05	**0.024**
SSP/TSP	1.95 (0.92)	3.31	0.0 (0.0)	0.00	**0.035**
MoP	0.07 (0.07)	0.67	0.0 (0.0)	0.00	0.595
Cowdung manure	1915.13 (139.82)	100	1639.62 (203.60)	96.16	0.313
Vermicompost	260.81 (39.14)	53.75	150 (50.00)	7.79	0.549

* In relation to the number of responses received

Hired and family labour use was higher in NFs than in the CFs by 23.40% and 46.20%, respectively (Table 3.7). Naturally, total labour use was also higher in NF (34.32%). But, since the proportion of family labour was higher in NF, the labour cost was lower in NF (calculation not shown in the table). However, this comparison is not conclusive since labour use in NF depends on land size, crop types, and access to farm machinery. Higher labour use in NF may be due to higher engagement of labour in farm operations such as composting and liquid manure preparation, and care of livestock (Gupta et al., 2020). On the other hand, appropriate mulching may reduce labour use in weeding. Unfortunately, we do not have access to enough scientifically validated research outputs that unequivocally demonstrate the effect of NF on farm labour use. Since many of the operations are met by family labour, family labour use was higher in NFs than in CFs. NF and related endogenous farming approaches are often criticised based on their higher labour requirement. However, family labour engagement may overcome this extra labour use and maintain a moderate cost of cultivation. Socio-cultural realities (type of family – nuclear vs. extended) and demographic factors (family size), along with local non-farm employment and migration opportunities, play important roles in ensuring family labour supply in NF.

Table 3.7: Labour use in natural and conventional farms

	Unit	N	Practising Natural Farms [Mean (SE of mean)]	N	Conventional Farms [Mean (SE of mean)]	t-sig.
Hired labour	Person-days/yr	115	84.97 (8.93)	37	68.86 (15.58)	0.374
Family labour		118	118.58 (8.11)	37	81.11 (13.88)	**0.024**
Hired: Family Labour	NA	115	66.96 (6.121)	37	78.55 (11.36)	0.358
Total Labour	Person-days/yr	118	201.41 (15.69)	37	149.95 (28.22)	0.112
Family labour Men	Person-days/yr	118	76.07 (6.50)	36	51.48 (10.39)	**0.062**

Family labour Women	Person-days/yr	113	44.41 (2.66)	37	31.02 (4.07)	**0.011**
Male: Female Labour	NA	113	157.61 (13.71)	36	137.99 (18.84)	0.461

Adopting good practices holds key to many agricultural development initiatives. This is an indicator of behavioural changes infused by prolonged educational interventions in the form of awareness campaigns, demonstrations and community mobilisation. Practising NF adopted all the 17 good practices listed below more frequently than CFs (Table 3.8). This is evidence of behavioural change among NF farmers due to persistent educational efforts by the implementing agencies in the form of demonstrations, community-level field schools, and green colleges. Although the sampled farms started NF at different points in time, it seems that the central pillars of NF (seed/seedling treatment, liquid manure) have been widely followed although mulching could be better streamlined. Several other practices are still not adopted by a majority of farms.

Table 3.8: Good practices followed by the practising natural farms and conventional farms

Good Practices	% of Practising Natural Farms adopted	% of Non-practising Farms adopted
1. Raised bed furrow irrigation	63.4	30.3
2. Seed and/or seedling treatment	71.6	30.3
3. Line sowing	41.9	21.2
4. Green manuring	50.0	15.2
5. Legume rotation	10.0	3.0
6. In-situ composting	2.7	3.0
7. Mulching	31.1	9.1
8. Liquid manure application	86.87	23.26
9. Biofertilizer application	33.77	16.28
10. Homemade biopesticide	30.46	11.63
11. Scaffold creepers	18.9	6.1
12. Seed production	4.1	3.0
13. Bird perch	23.8	11.6
14. Agroforestry	21.9	11.6
15. Azolla cultivation	35.1	12.1
16. Vermicompositing	34.4	16.3
17. Local sale of farm produce	25.8	14.0

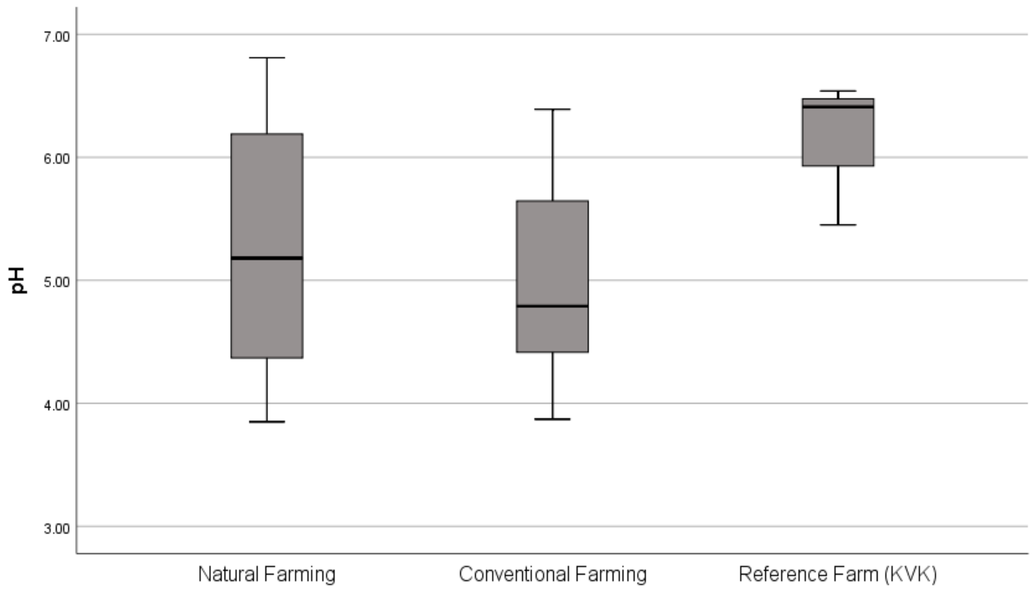
3.4 Soil physicochemical properties

Apart from NF and CF, we assessed the soil parameters of Divyayan Krishi Vigyan Kendra (a first-line extension of the Indian Council of Agricultural Research) to appreciate the differences between on-station and on-farm conditions. We separately compared these three groups, and then only between NF and CF. We observed a significant group mean difference for Organic C, EC, Available P^2O^5, Available K^2O, Zn, and Cu (Table 3.9). For all these parameters the significantly higher group mean was for the KVK farm. However, when we reduced the comparison to NF vs. CF, we found a significant mean difference in available K_2O in favour of natural farms. Nevertheless, we notice a higher mean value of pH (closer towards normal), organic C, available N, available K_2O, and Zn in NF and a higher mean value of EC, Available P_2O_5, Cu, Fe, and Mn in CF. Higher Zn availability is particularly important because of reported Zn deficiency in Jharkhand soils (Shukla et al., 2018). To give the readers a granular description of the diverse nature of soil samples, we have given the distribution of samples in terms of 10 analysed parameters (Figs. 3.1a-3.1j). Higher values of KVK suggest the theoretical possibility of improving the on-farm soil fertility of NF.

Table 3.9: Soil properties of practising farms, conventional farms, and reference farm (Divyayan KVK, Ranchi)

	Parameters	Practising NF	Non-practising	KVK	NPar Sig. (U) /NPar Sig (W)*
1	pH	5.2568	5.0009	6.1333	0.560, 0.158
2	EC	0.3764	0.5400	1.06	0.638, **0.078**
3	Organic C	1.1705	0.9073	2.66	0.299, **0.015**
4	Available N	273.40	270.2636	257.1667	0.807, 0.895
5	Available P_2O_5	238.4909	267.3636	1061.3667	0.895, **0.039**
6	Available K_2O	451.5045	404.8727	1154.9667	**0.047**, **0.082**
7	Zn	1.9605b	1.6264b	3.1033a	0.264, **0.011**
8	Cu	1.5841b	1.6627b	4.6533a	0.866, **0.018**
9	Fe	46.4741	66.91	148.56	0.807, 0.189
10	Mn	32.7005	33.3273	34.71	0.638, 0.758

* NPar Sig. (Mann-Whitney U).: NF vs. Conventional; NPar Sig. (Kruskal-Wallis): NF vs. Conventional vs. KVK farm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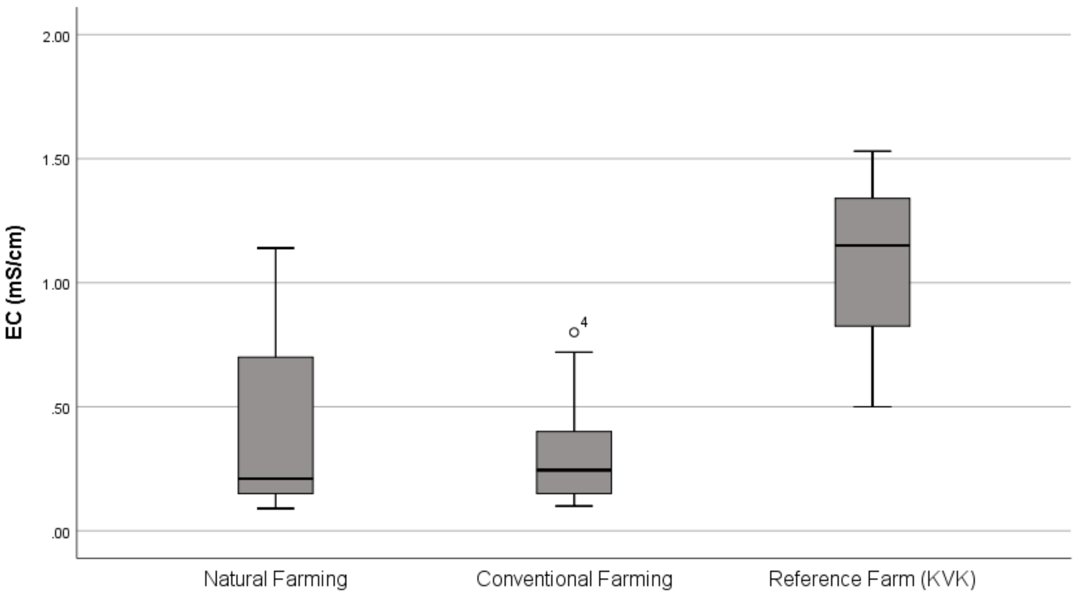
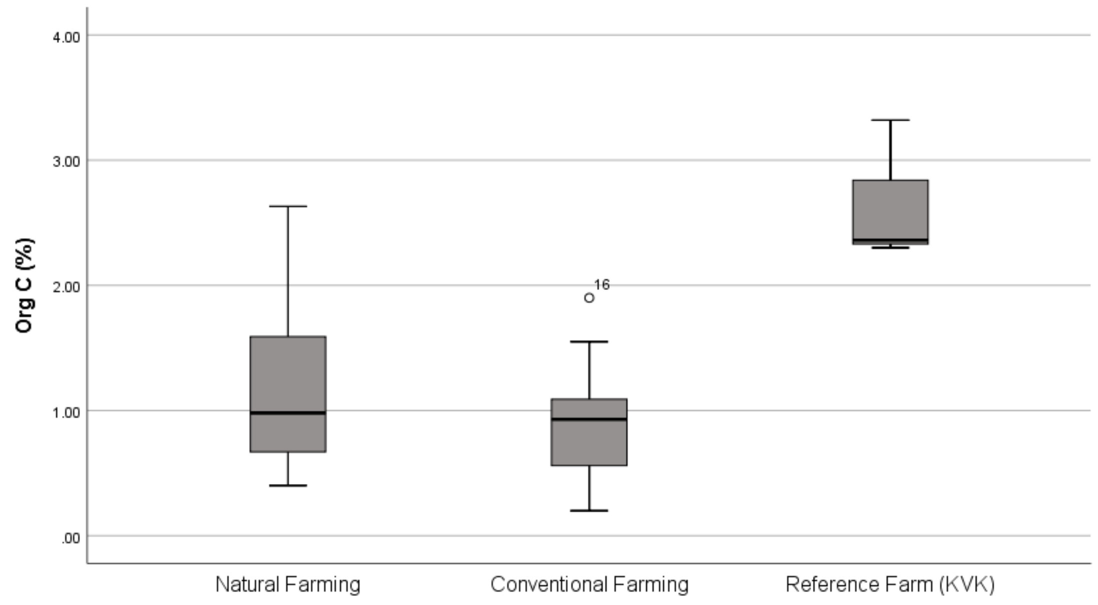
6.00
5.00
4.00
3.00
pH
Natural Farming
Conventional Farming
Reference Farm (KVK)

A

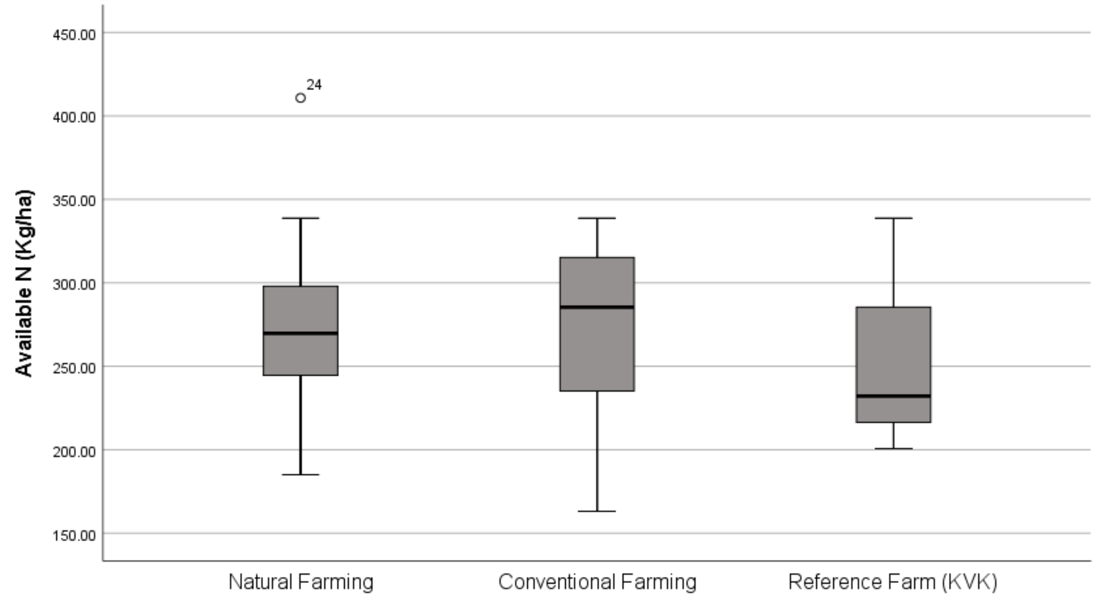

2.00
1.50
1.00
.50
.00
EC (mS/cm)
4
Natural Farming
Conventional Farming
Reference Farm (KVK)

B



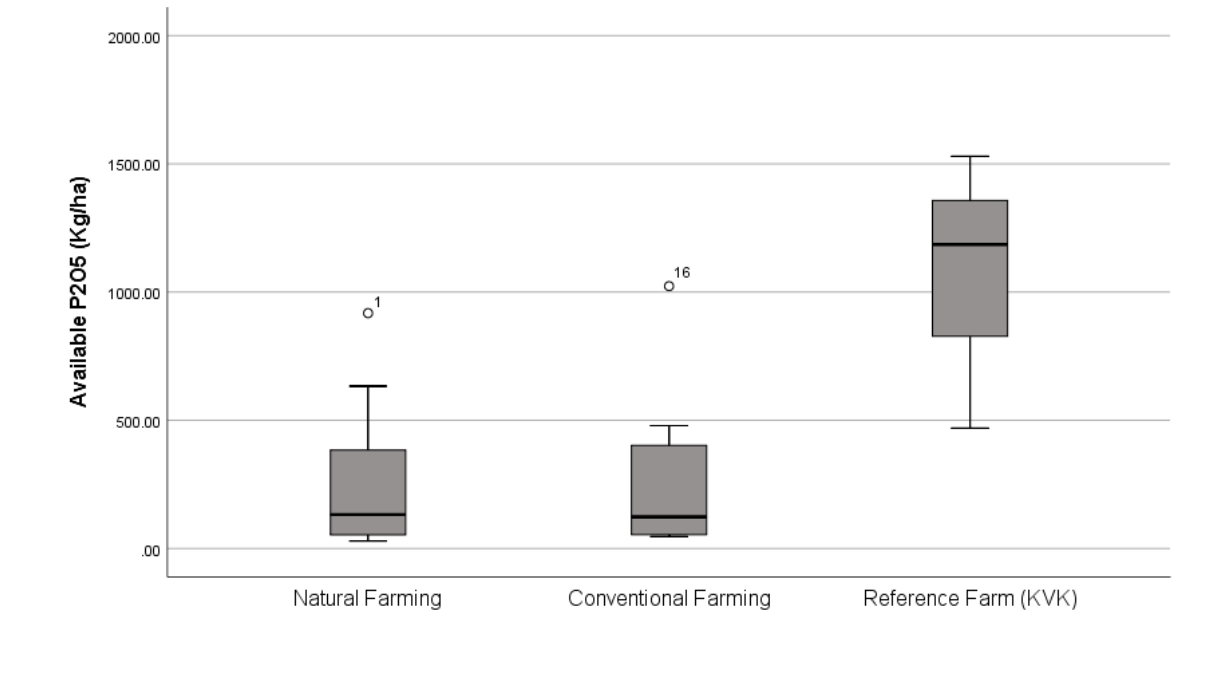
4.00
3.00
2.00
1.00
.00
Org C (%)
16
Natural Farming
Conventional Farming
Reference Farm (KVK)

C

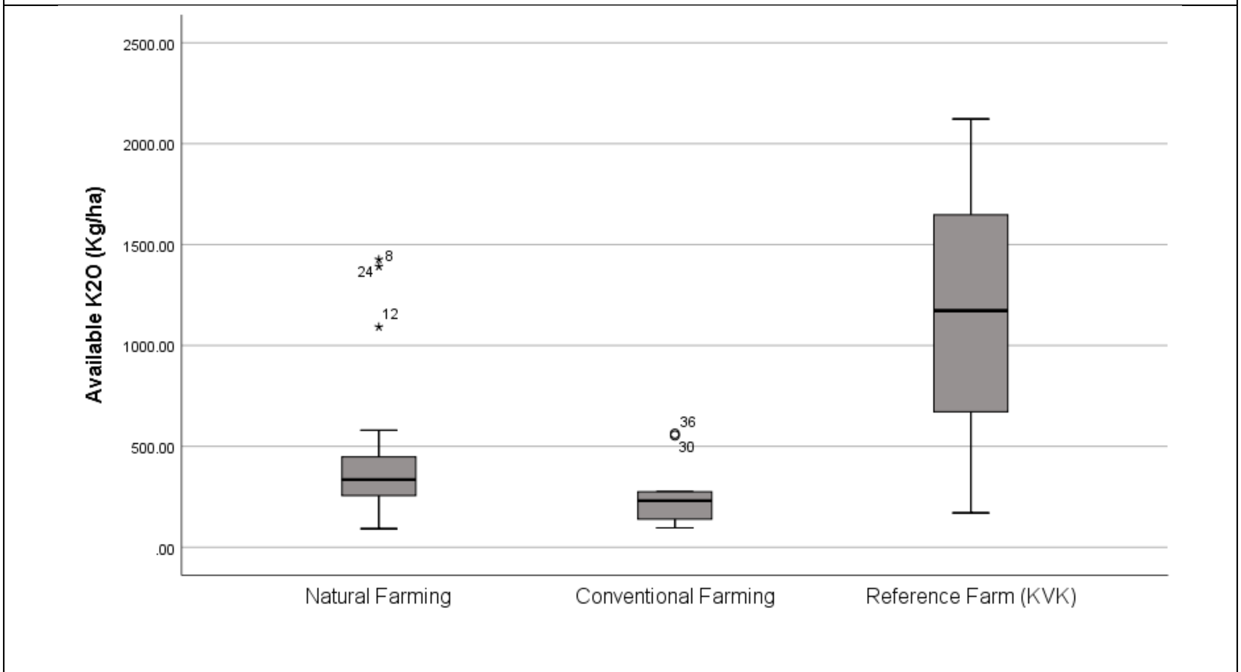


450.00
400.00
350.00
300.00
250.00
200.00
150.00
Available N (Kg/ha)
24
Natural Farming
Conventional Farming
Reference Farm (KVK)

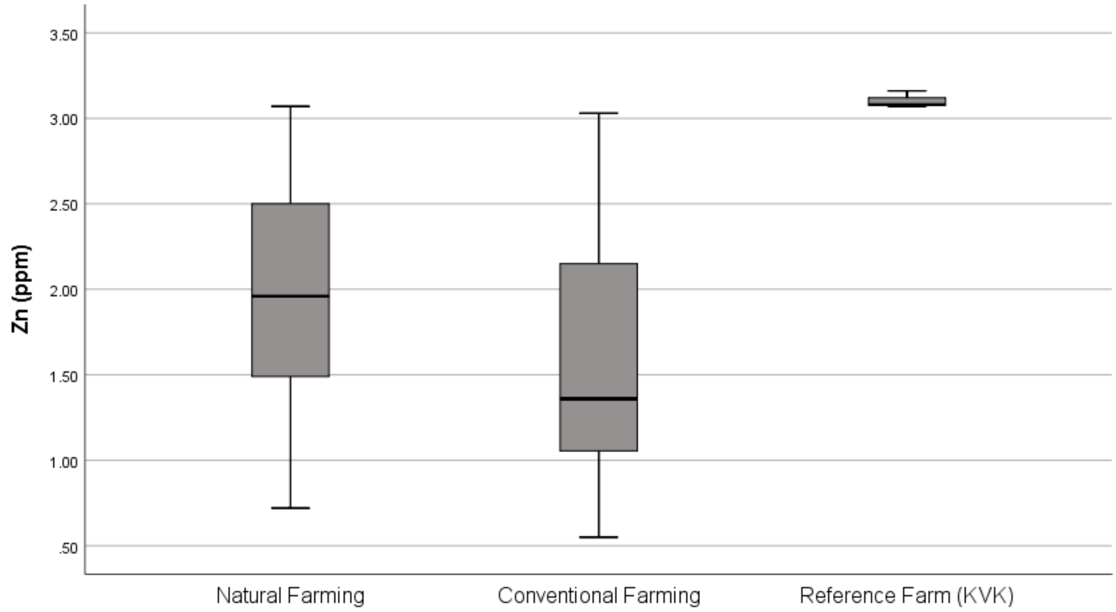
D


Available P2O5 (Kg/ha)
2000.00
1500.00
1000.00
500.00
.00
1
16
Natural Farming
Conventional Farming
Reference Farm (KVK)

E

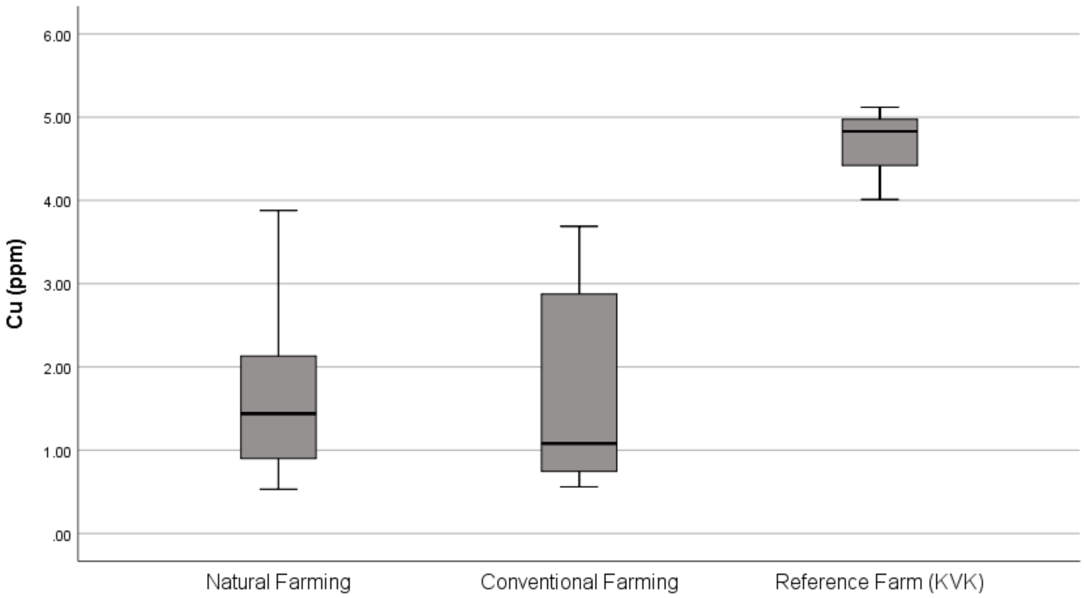

Available K2O (Kg/ha)
2500.00
2000.00
1500.00
1000.00
500.00
.00
8
24
12
36
30
Natural Farming
Conventional Farming
Reference Farm (KVK)

F



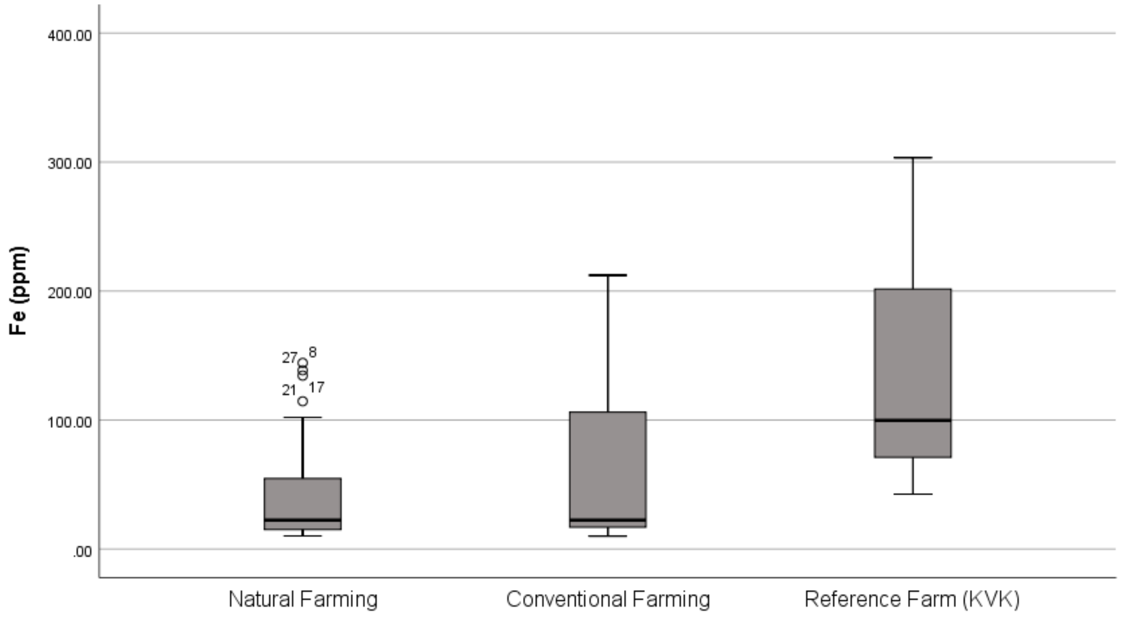
3.50
3.00
2.50
2.00
1.50
1.00
.50
Zn (ppm)
Natural Farming
Conventional Farming
Reference Farm (KVK)

G

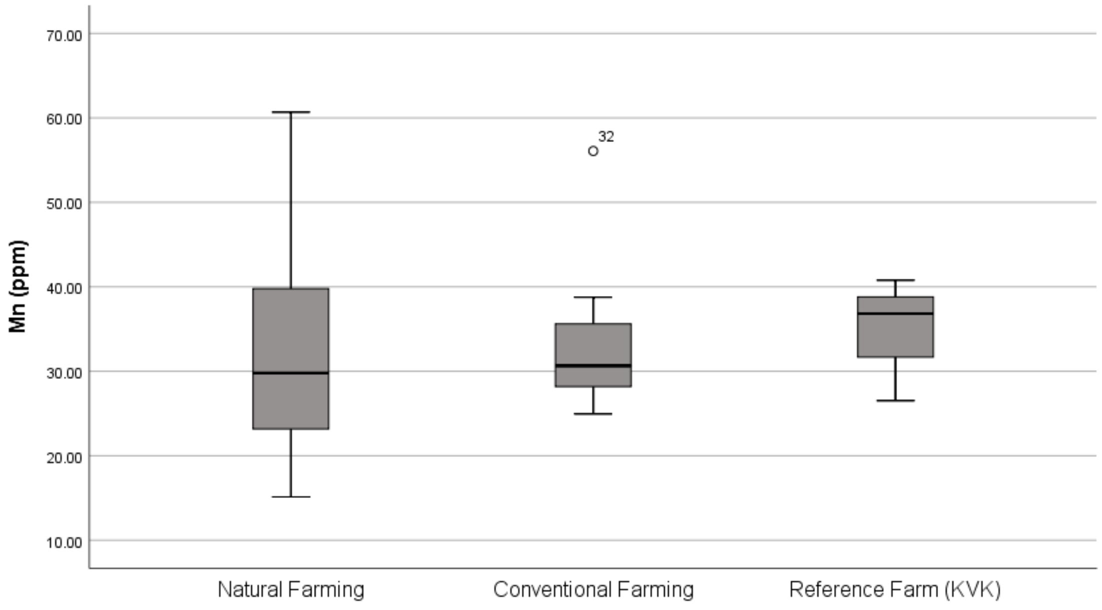


6.00
5.00
4.00
3.00
2.00
1.00
.00
Cu (ppm)
Natural Farming
Conventional Farming
Reference Farm (KVK)

H



I



J

Figs. 3.1a-3.1j: Distribution of ten soil properties in natural, conventional and reference (KVK) farms – a) pH, b) EC, c) Organic C, d) Available N, e) Available P_2O_5, f) Available K_2O, g) Zn, h) Cu, i) Fe, j) Mn

Taking all the parameters together, Fig. 3.2 represents a comparative view of ten soil physicochemical properties. Higher Organic C is reported to have a relationship with soil microbial activities thus influencing the availability of several plant nutrients. The K_2O content of the soil was high; but, given the fact that little or no K is applied in the soil, higher content in NF is beneficial in the long run.

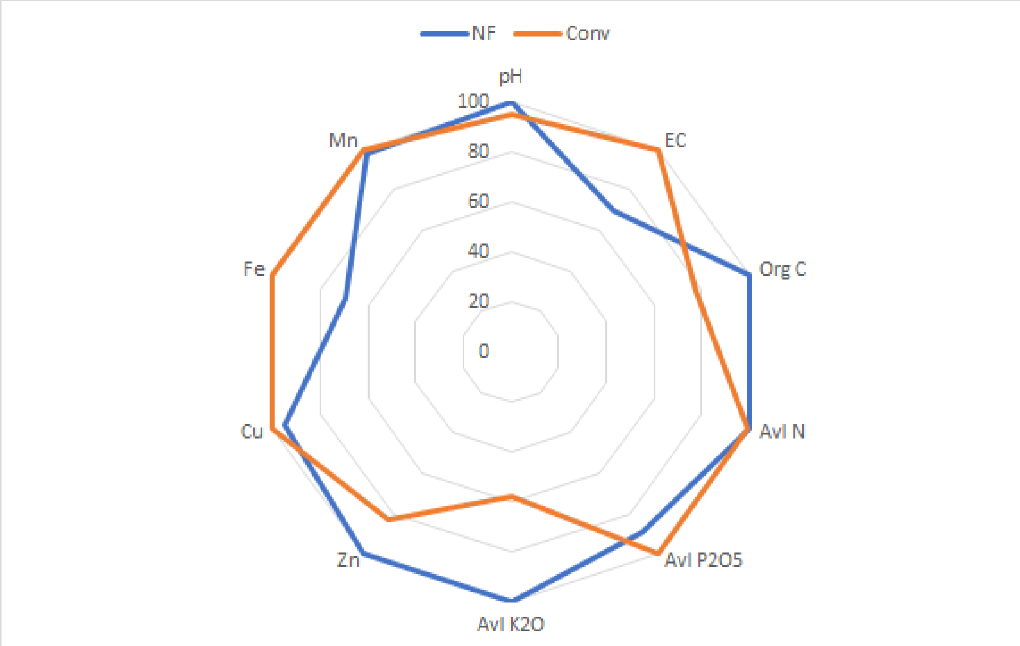


Fig. 3.2: Comparison of natural and conventional farms in terms of ten physicochemical parameters of the sampled soil. Mean values are standardized in a 0-100 scale for simple representation.

3.5 Soil microbial status

We observe the total bacteria, actinomyces and fungi for the NF, CF, and KVK farms. Neither a non-parametric Kruskal-Wallis (involving three groups) nor a non-parametric Mann-Whitney (NF vs. CF) could find a significant difference in any of the three microbes populations (Table 3.10a). The total bacteria and fungi count was higher in CF, whereas the actinomycetes count was higher in NF. Except for total bacteria, other counts were the highest in the KVK farm.

Table 3.10a: Total bacteria, actinomycetes and fungi in the soils of natural, conventional and KVK farm

	Parameters	Practising NF	Non-practising	KVK	NPar Sig. (U) /NPar Sig (W)*
1	Total bacteria	263.61×10^9	488.82×10^9	187.67×10^9	0.076/0.13
2	Total actinomycetes	112.36×10^5	91.61×10^5	607.33×10^5	0.611/0.089
3	Total fungi	47.94×10^3	52.61×10^3	82.22×10^3	0.925/0.315

* NPar Sig. (Mann-Whitney U).: NF vs. Conventional; NPar Sig. (Kruskal-Wallis): NF vs. Conventional vs. KVK farm

Table 3.10b presents the range of antibiotic-resistant bacterial (ARB) populations and various groups of plant beneficial microbes in three different input-management systems. In the organic input system (KVK farm), the soil contains an approximate average of **24.2** X 10^6 CFU/g of free-living nitrogen-fixers (FNF's). Comparatively, the inorganic fertilizer input system (conventional) houses a population of FNF's at **6.87** X 10^6 CFU/g of soil, while natural farming soils boast a thriving average of **13.24** X 10^6 CFU/g of these beneficial microorganisms.

Table 3.10b Free Living Nitrogen Fixer, Phosphate Solubilizing Bacteria, Potassium Solubilizing Bacteria, Ampicillin Resistant Bacteria, Tetracycline Resistant Bacteria

Input type	Free-living, Nitrogen Fixers ($X10^6$ CFU/g)	Phosphate Solubilizing Bacteria ($X10^7$ CFU/g)	Potassium Solubilizing Bacteria ($X10^6$ CFU/g)	Ampicillin Resistant Bacteria ($X10^5$ CFU/g)	Tetracycline Resistant Bacteria ($X10^5$ CFU/g)
KVK farm (organic)	6.9±3.1 – 55.3±16.9	2.33±0.66 – 3.96±1.41	3.23±0.26 – 3.70±0.17	0.93±0.27 – 1.24±0.10	0.24±0.32 – 1.60±1.22
Conventional farming (inorganic)	1.7±0.85 – 14±0	0.14±0.02 – 47.33±4.35	0.66±0.66 – 4.23±0.15	0.07±0.05 – 2.5±0.24	0.04±0.01 – 0.84±0.13
Natural farming	1.6±0.76 – 36.4±5.2	0.15±0.02 – 71.20±9.14	0.53±0.11 – 4.76±0.40	0.007±0.006 – 2.01±0.54	0.08±0.01 – 1.78±0.19

The organic input system hosts a mean population of **3.26** X 10^7 CFU/g of Phosphate Solubilizing Bacteria (PSB). The inorganic fertilizer input system boasts an even higher average of **33.98** X 10^7 CFU/g of PSB. For the natural input system, PSB flourishes with a mean of **19.81** X 10^7 CFU/g in the soil.

The organic input system nourishes the soil with a mean population of **3.45** X 10^6 CFU/g of Potassium Solubilizing Bacteria (KSB). Inorganic fertilizer input system, on the other hand, supports a slightly lower average of **2.70** X 10^6 CFU/g of KSB. In the natural input system, the soil teems with a mean of **3.35** X 10^6 CFU/g of Potassium Solubilizing Bacteria (KSB).

The mean population of Ampicillin-resistant bacteria in the organic input system is **1.06** X 10^5 CFU/g of soil, while in the inorganic input system, it is **0.55** X 10^5 CFU/g. In the natural input system, the Ampicillin-resistant bacteria thrive with an average of **0.69** X 10^5 CFU/g.

The Tetracycline-resistant bacterial population in the organic input system averages **0.79** X 10^5 CFU/g, while in the inorganic input system, it is lower at **0.32** X 10^5 CFU/g. In the natural input system, the Tetracycline-resistant bacterial population thrives at an average of **0.53** X 10^5 CFU/g.

Summarily, KVK farms demonstrated higher value for nitrogen-fixers and Potassium solubilising bacteria, and conventional farms demonstrated higher phosphorus solubilising bacteria. Conventional farming showed less number of Ampicillin and Tetracycline resistant bacteria.

Morphologically distinct FNF, PSB KSB are chosen for their efficacy assay and finally efficient strains will be identified by 16S ribotyping. Multi drug resistant screening was performed for ARB strains that are morphologically distinct. Finally, two multidrug resistant strains were isolated which will be identified using 16S ribotyping. This information will be published as peer-reviewed publications.

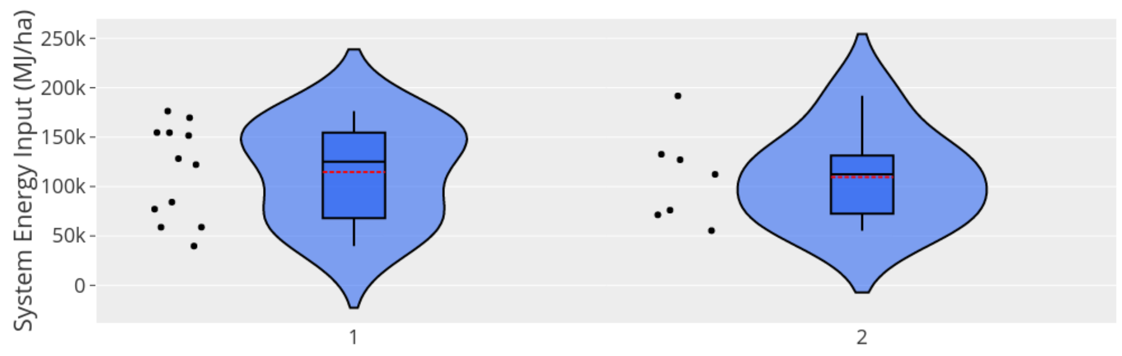
3.6 Energetics of the System

We used different energy indices, namely system energy input (SEI), net energy gain (NEG), energy ratio (ER), specific energy (SE), and energy productivity (EP) to compare the energy efficiency NFs and CFs (Table 3.11; Figs. 3.3 a,b c). We found a lower average SEI (52.34%), and SE (65.2%), and thus, a higher NEG (20.19%), ER (61.62%) and EP (71.86%) in the NF. Except for NEG, all other differences are statistically significant. Energy is considered to be an absolute denominator for comparing efficiency in farming systems and the energy budget for farming systems is considered an additional parameter to identify future farming systems. We found NF significantly more energy efficient than CFs.

3.11 Energy use of cropping system in natural and conventional farms

	Parameters	Practising NF	Non-practising	NPAr. (U) Sig.
1	System energy input (MJ/ha)	13849.92 (2792.77)	29059.40 (4073.29)	**.010**
2	Net energy gain (MJ/ha)	100801.33 (12138.12)	80450.60 (15986.82)	0.299
3	Energy ratio	10.24 (1.15)	3.93 (0.41)	**.000**
4	Specific energy	0.87 (0.13)	2.5 (0.46)	**.000**
5	Energy productivity	1.67 (0.40)	0.47 (0.07)	**.000**

In absolute terms, the energy use in CFs is well in line with authentic literature (22,486–28656 MJ/ha) (Yadav et al., 2017) thus providing confidence to our study report. Literature suggests that the relative amount of energy input in conventional systems involved 44–54% for chemical fertilizers, 13–17% for land preparation, 12–15% for diesel and 11–14% for human labour. Our data suggest machines used for land preparation (~50%) and fertilizers/manures (~30%) are the most important sources of energy use. Thus, fertilizer dose rationalization (or non-use) and appropriate mechanisation tools for land preparation (energy efficient) can be effective means of transitioning farming systems to more energy efficient systems.



A

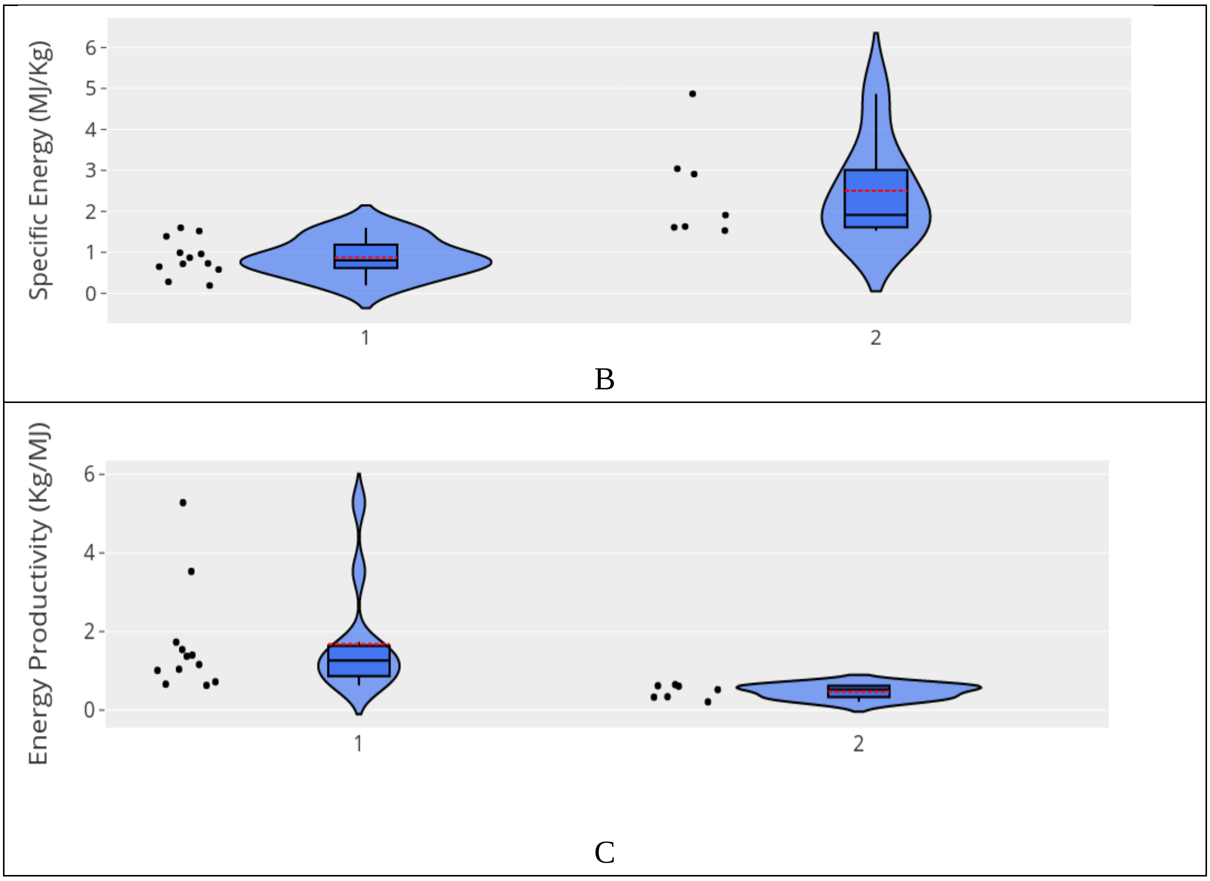


Fig. 3.3: Estimated System Energy Input (a), Specific Energy (b), and Energy Productivity (c) from natural (1) and conventional (2) (case study) farms. The box and red line indicate the interquartile range and median, respectively. The solid violin represents the non-parametric kernel density of the distribution.

3.7 Emissions from the System

We used GHG emissions (GHG) and yield-scaled GHG emissions (YSGHG) to compare the emission potentials from NFs and CFs (Table 3.12; Figs. 3.4a,b). We found a lower average GHG (13.22%) and YSGHG (28.35%) for the case study farms. However, the differences were not statistically significant. Emissions from CFs were lower than the reported literature (4.8-12.9 t/ha), suggesting a much more impact in input-intensive farming. A crude estimate suggests that this 13.22% reduction in emissions might allow us to reduce emissions (CO_{2eq}) by 4.08 Lt for the state of Jharkhand. Literature and our case studies suggest that fertilizers/manures and fossil fuels for land preparation and irrigation are two major sources of indirect and direct emissions from farming systems (Ray et al., 2018). Managing these two practices by improved nutrient management and irrigation through renewable energy-driven mechanisms (solar power) would make NF environmentally sound. Moreover, legume-based systems will result in lesser emissions than cereal and oilseed-based systems because of a significant reduction in applying nitrogenous fertilizers.

Table 3.12 Emissions from the natural and conventional farms

	Parameters	Practising NF	Non-practising	NPAr (U) Sig.
1	GHG emissions	1488.83 (159.65)	1715.55 (301.50)	0.592
2	Yield-scaled GHG	0.1135 (0.02)	0.1584 (.04)	0.227

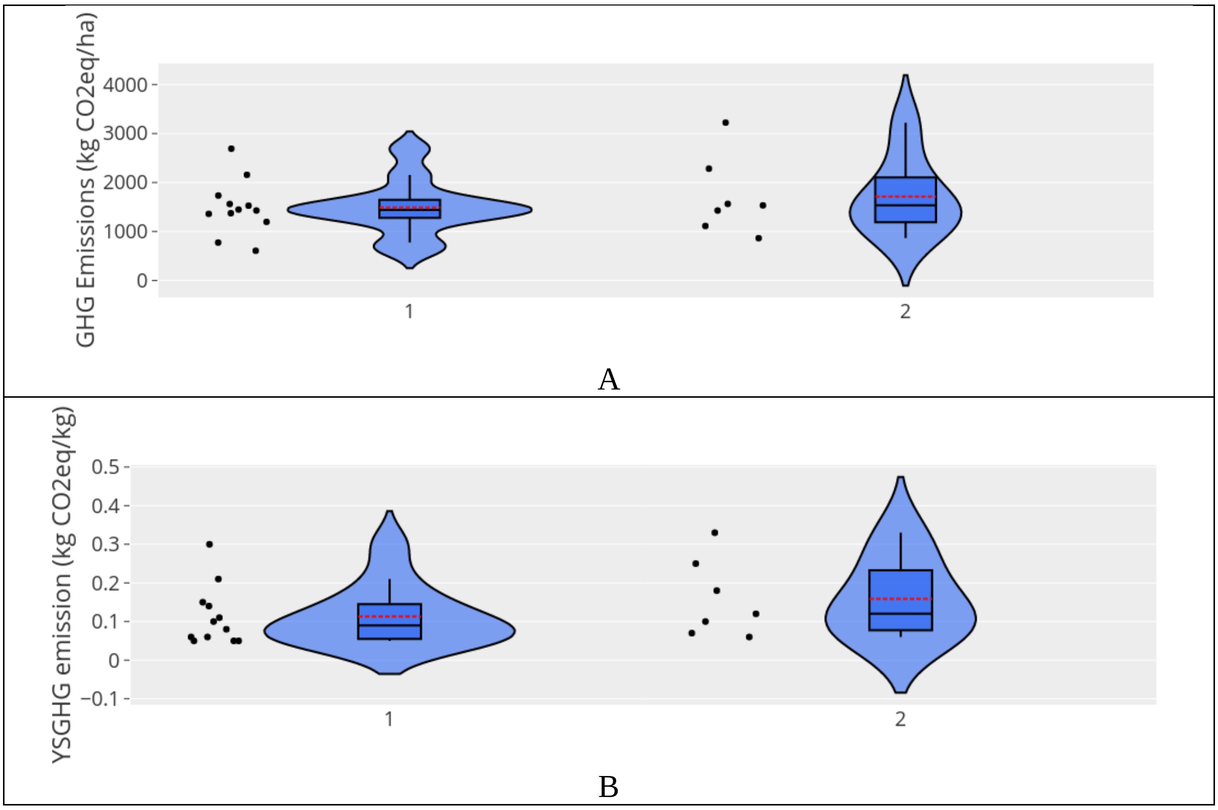


Fig. 3.3: Estimated GHG Emissions (a) and Yield-Scaled GHG Emissions from natural (1) and conventional (2) (case study) farms. The solid violin represents the non-parametric kernel density of the distribution.

3.8 Multi-indicator comparison

We have presented the quintessential characteristics of the farming systems namely productivity, profitability, energetics and emissions from NF and CF in a retrospective. The thirteen indicators that we use are - Paddy yield (PY), Rice Equivalent Yield (REY), Cost of Cultivation (CoC), Labour Engagement (Lab), Hired: Family Labour (H:F), Profitability (Prof), System Energy Input (SEI), Net Energy Gain (NEG), Energy Ratio (ER), Specific Energy (SE), Energy Productivity (EP), GHG Emissions (GHG), and Yield-scaled GHG (YSGHG) (Figs. 3.4a,b). Except for PY, Lab, and Prof, NF fared a more desirable outcome in terms of all other parameters (Fig. 3.4b). This observation of a marginal drop in yield, profitability (especially in the absence of a price premium), and labour use is in consonance with practitioners’ experience. But, the gains in terms of energetics parameters and emissions make NF a more stable, sustainable and climate-resilient option for smallholders. These environmentally desirable options stem from the reduced use of fossil fuel and synthetic fertilizers, thus curbing the possibility of direct environmental externalities (pollution). It is understandable that there might be a trade-off between yield and profitability and environmental outcomes from NF, but a pragmatic step is to overcome this trap by contriving on-farm and extra-farm innovations. e.g., price premium/branding or value addition for offsetting price, and crop diversification and/or sustainable intensification for offsetting reduced production.

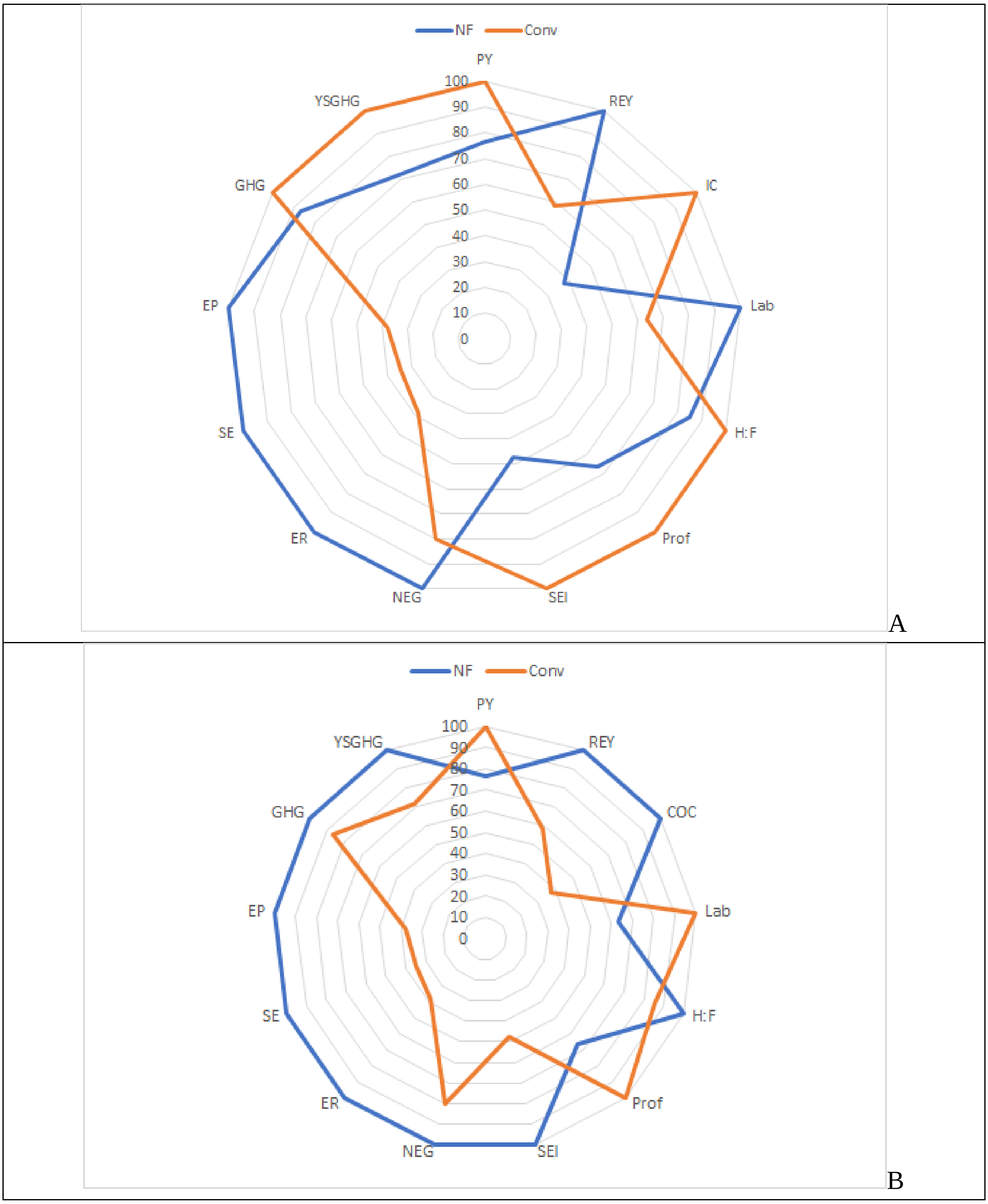


Fig. 3.4: Multicriteria comparison of Natural and Conventional farms in terms of – Paddy yield (PY), Rice Equivalent Yield (REY), Cost of Cultivation (CoC), Labour Engagement (Lab), Hired: Family Labour (H:F), Profitability (Prof), System Energy Input (SEI), Net Energy Gain (NEG), Energy Ratio (ER), Specific Energy (SE), Energy Productivity (EP), GHG Emissions (GHG), and Yield-scaled GHG (YSGHG). A) Representation of original values standardized on a 0-100 scale; B) Representation of parameters in a 0-100 scale according to their desirability (higher value more desirable than lower value).

3.9 Expansion of the natural farming practices

Expansion and spillover of NF are important and overcoming the initial chasm from 'few to a mass' is critical for technology upscaling. A high proportion (94.9%) of sampled farms showed continuity and proliferation (66.46% increase in acreage) of NF practices across the locations (Table 3.13). The increase in NF area was high (30.06%-207.66%) when the practice was started on the homestead plots (17.91-48.57 decimal, on average) and later expanded to the main field. When started on the main field, the expansion was relatively slower (10.89%-46.21%), except for Giridih (136.34%). However, the expansion might well be connected to the inception of NF in an area, which we did not consider.

Table 3.13: Expansion of natural farming practices among the sampled farms in Jharkhand

	Mean acreage at the beginning (decimal)	Per cent of farmers continuing	Current* mean area of natural farming (decimal)	Mean per cent change in the acreage
Deoghar (23)	184.78 (23.81)+	91.3	270.17 (32.95)	46.21
East Singbhum (17)	201.52 (14.05)	100	223.46 (20.82)	10.89
Giridih (23)	124.37 (15.31)	87	293.93 (35.47)	136.34
Hazaribag (16)	48.57 (11.88)	100	63.17 (13.97)	30.06
Khunti (31)	37.99 (5.31)	100	116.88 (18.81)	207.66
Latehar (16)	29.46 (5.34)	100	55.11 (8.50)	87.07
Ranchi (10)	17.91 (4.34)	70	122.47 (63.66)	583.81¥
Saraikela (21)	154.32 (23.86)	100	180.55 (27.20)	16.20
POOLED (157)	102.41 (7.76)	94.9	170.47 (11.6)	66.46

* In 2022; +: Mean (SEM); ¥: May be ignored for the small number of observations

Farmers' self-reporting suggests a slow but significant social learning of NF among the farmers. Sharing of farm-related information among peers is a well-established fact and often a precondition to the diffusion of innovations. The project interventions in the form of farm schools and green colleges facilitated knowledge exchange and more than one-third (35.7%) of the practising farmers shared information and skill with their group members (Table 3.14). How this social learning translates into NF adoption and diffusion in the area will be a scope of further inquiry and monitoring.

Table 3.14: Spillover of the natural farming practice through information sharing

	Neighbours	Fellow farmers	Relatives	Group members
N	151	151	145	151
% of farmers shared	37.7	15.9	13.1	35.7

3.10 Farm Resource Interaction in natural and conventional farms

We recorded the flow of material, energy, and space sharing between all possible pairs of elements in a farming system (details in Section 2.5.8) and aggregated them for all case study farms. Hence, we developed an aggregated (group) matrix for NF and another for CFs (Figs. 3.5a, b). The individual cells represent the abundance of a linkage – covering all case study farms – between two farm components. We find a stark similarity between NF and CF in terms of their resource interaction pattern. This might be due to the fact that most of the sampled farms had been following a traditional crop-livestock design, where homestead played a central role in resource recycling. A small proportion of farms demonstrated unique resource interaction due to micro-level factors like access to common property resources and choice of livestock. We also observe a void in the interaction involving CPR and Fallow land (ignoring the contextuality of piggery and use of canal water), which may add to the viability of NF in resource-scarce regions. This might need science and technology intervention and community-level institutions to revive CPR and fallow land for producing farm inputs (fodder, biopesticides, biomass, fuel) for natural farms.

Fig. 3.5: Abundance of interactions between all possible pairs of farm resource components – a) Natural farms, b) Conventional farms

However, we dug deeper to examine the structural aspects of the NF and CF to understand the central binding agents in those farms. We found that except for Connectedness, NF demonstrated higher values of all parameters such as Average Degree, Degree Centralization, Density, Connectedness, Transitivity and Closure, Mutuals, and Dyad Reciprocity (Borgatti et al., 2018) (Table 3.15). But, none of these differences was statistically significant. Summarily, NF showed higher per-element connections (average degree), the centrality of a lesser number of farm elements (centralization), average linkages per farm resources (density), the chain of resource interactions beyond dyadic relations (transitivity), and two-way resource flow (mutuals and reciprocity).

Table 3.15: Structural characteristics of resource interaction networks in natural and conventional farms.

Sl. No.	Parameter	Practising Natural Farm	Non-practising Farm
1	Average Degree	6.857	6.429
2	Degree Centralization	0.308	0.218
3	Density	0.527	0.495
4	Connectedness	0.665	0.725
5	Transitivity/Closure	0.833	0.773
6	Mutuals	0.473	0.407
7	Dyad Reciprocity	0.811	0.698

Figures 3.6a-3d suggest a slightly dissimilar pattern of resource use patterns in NF. Cattle, manure pits, and paddy fields form the core of NF resource use networks, and the red linkages imply the highest tie strength (in a statistically defined Very High-High-Moderate-Low classification). Homestead, well, kitchen, small livestock, and tree formed the High linkage (green lines).

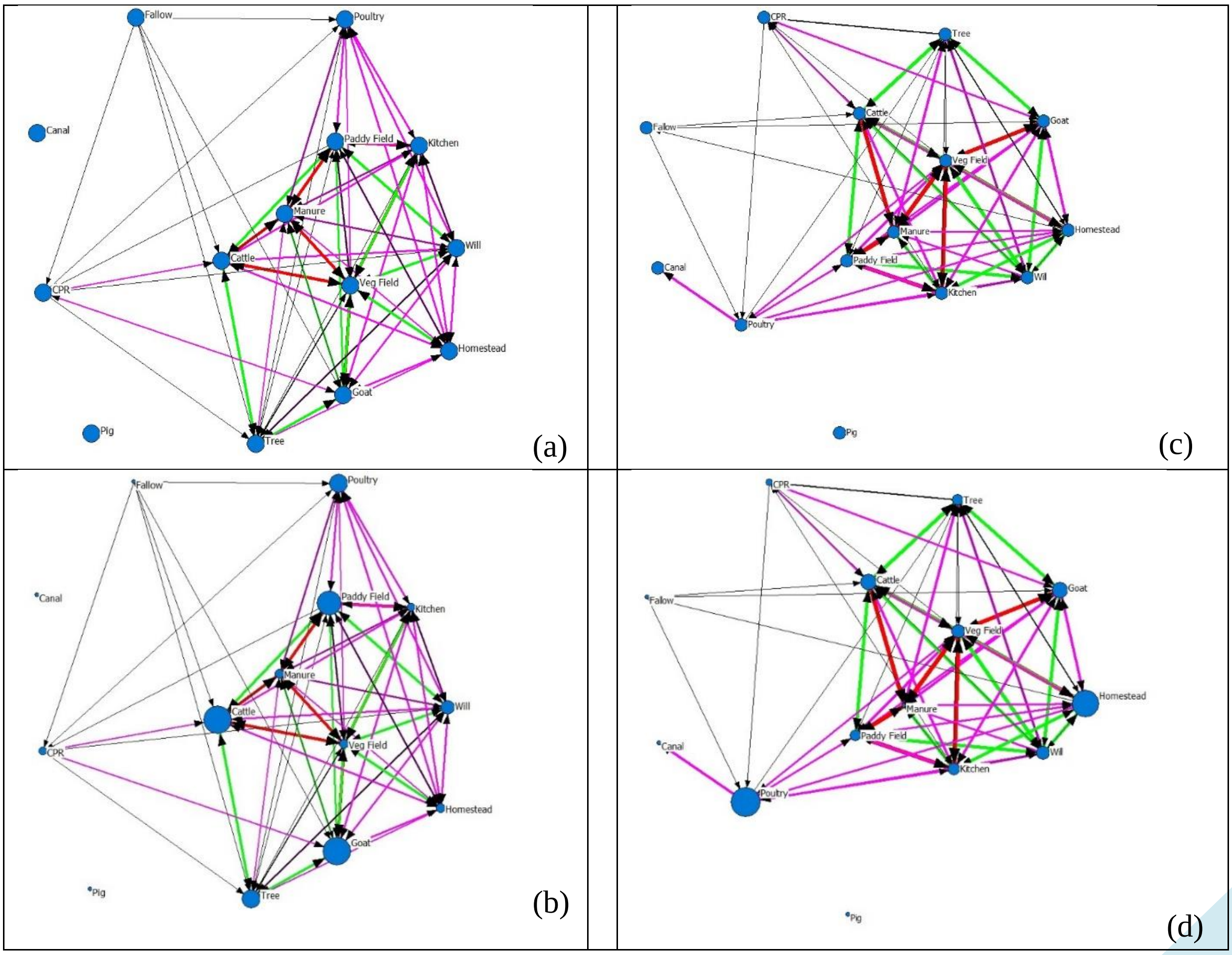


Fig. 3.6: Farm resource interaction structure in practising natural farms – a) nodes not scaled, b) nodes scaled by their betweenness centrality. The nodes represent farm components and the edges are their interactions. Red lines indicate strong tie strength between a pair of farm components. Green, pink, and black lines represent moderate, low, and negligible tie strength.

Fig. 3.6: Farm resource interaction structure in conventional farms – c) nodes not scaled, d) nodes scaled by their betweenness centrality. The nodes represent farm components and the edges are their interactions. Red lines indicate strong tie strength between a pair of farm components. Green, pink, and black lines represent moderate, low, and negligible tie strength.

For CF, Very High tie strength involved cattle, manure pits, paddy fields, homesteads, vegetable fields, kitchens, and goats. We anticipate that Cattle-Manure pit-Vegetable field (mostly in homestead)-Paddy field nexus is traditionally practised by all the farms, which may be extended to other farm elements (e.g., tree, poultry, kitchen, CPR, and Fallow) to establish circularity and endogeneity in the NF. However, this is an impressionistic observation and needs validation. Fig. 3.6b suggests that paddy fields, cattle and goats have a higher betweenness and are thus important to expand the benefits of resource interaction in the NF.

4. Reflections, Conclusions and Recommendations

In Section 1.1 of this report, we observed that the ontological nature of 'natural farming' is loaded, debated and, thus, normative in many instances. Definitions may work on papers, which are often institutionally ratified. However, in practice, NF represents a set of principles rendering its study difficult. Thus, it is difficult to define and compare natural farms in farmers' fields when defined models are not followed completely. This difficulty, stemming from ontological crises and real-world phenomena, affects the epistemology of NF research and makes the study procedures (and outcomes) open to criticism and cynicism. This is more so because of the long tradition of reductionist research in agricultural sciences that sets a handful of short-term policy indicators (yield, profitability) as the basis for judging technological success. We accept many of these concerns apply to our present study – despite several conscious methodological choices – and readers are encouraged to apply their logical discretion to judge the validity of our findings. Given below are a set of observations and recommendations that stream out from our field survey, laboratory analysis, qualitative interviews, and relevant literature synthesis.

The NF and CF were not different in terms of any background characteristics (demographic, socio-economic, and assets) except irrigation coverage. We mentioned that the 'comparison' in our analysis is not designed to trace the 'impact' of NF, but rather a basis to appreciate the report in terms of the differential background of NF and CF. Despite several years of NF practice in some districts, given the limited impact that NF might have created on the practising farmers, it is unlikely that the socio-economic status and asset ownership are an outcome of NF. The same holds true for irrigation coverage. Irrigation seems more of a driver and not an outcome in a dry region, where enhancing the access to irrigation on NF is an input-intensive proposition (e.g., a river lift irrigation) in the short run. Also, we have reason to support the **importance of irrigation in accepting NF and enhancing its acreage** as (indirectly) suggested by the regression analyses and personal interviews. We also find the otherwise similar background of NF and CF helpful for some of the inferential analyses where an explicit matching technique (e.g., propensity score matching) could not be employed due to data insufficiency.

We did not find any effect of NF on several system outcomes (system cost of cultivation, system gross revenue, system profitability, and paddy yield). Only the cost of input was reduced due to less or no application of synthetic fertilizers and pesticides. However, we anticipate, slightly higher labour costs and slightly reduced system yield cancelled out this advantage, and we found no significant differences between NF and CF in terms of profits and profitability. Such observation also stems from the fact that the CFs were not practising input-intensive farming and a portion of the NF were still using fertilizers. Moreover, in several districts, NF was practised on the homestead or small plots thus its benefit was not clearly manifested. **We strongly advocate a scale-up drive on the same farms (in addition to spreading to other areas) until the economic benefits for farmers are clearly established.**

We could not find any statistically significant difference between the NF and CF in terms of most of the soil physicochemical and biological counts (not activity) except available K_2O.

Organic C, available N, and Zn were slightly higher in NF, whereas available P_2O_5, Cu, Fe, and Mn were higher in CF. Such smaller differences may exist when NF practice is not a 'copybook' and the practice is in the initial stages at certain locations. Since biological fixation from the atmosphere is possible only for nitrogen, NF could limit the supply of other nutrients (Smith et al., 2020). From that perspective, **monitoring of major nutrient availability is required to avoid possible nutrient mining from NF plots**. We did not also observe significant differences in terms of microorganism counts between NF and CF, although the absolute number of microorganisms was comparable to 'fertile' soils. Although microorganism count is only an indication of NF's positive impact on the soil (which is still not significantly higher in the study locations), we are further **examining the enzymatic activities** of the microorganisms and trying to **identify/characterize the group of microorganisms responsible for increasing nutrient availability** in the soil. We recommend **adding the study of enzymatic activity** (in addition to microbial count) and screening microorganisms to identify **novel consortiums** (Mukherjee et al., 2023).

The application of synthetic fertilizers, especially di-ammonium phosphate, was significantly less among the NF than CF. Overall, synthetic fertilizer use was less and the application of organic nutrient sources was high among NF. This observation is crucial since the lower input use transition to improved system performance (energy and emission) under normal farm management practices. However, reduced fertilizer application leading to improved profitability is contingent upon the extra-farm factor (e.g., market) and requires additional system intervention. Refer to Fig. 4.1 to understand the complexity. **We recommend that close monitoring is in place to ensure farmers are using reduced fertilizer and balanced organic input by the time a project confirms that an NF is 'practising'**. This is important because a proportion of farmers in the project location is using synthetic fertilizers. Also, there are views inside the public research agencies (unpublished claim; based on personal communication with the highest level of sustainable agriculture researchers) that NF should be replaced by an 'integrated' means of plant nutrition management.

Both hired and family labour use was higher in NF most probably for preparing composts and liquid manures and taking care of livestock. Based on a crude estimate we assume the labour cost was lower in NF because of the engagement of a higher proportion of family labour. However, this endogenous supply of labour is mediated by family type and size, and migration of male members. We suggest that a farm typology (considering land size, and family type and size) is developed to understand **which section of smallholders are more capable of managing NF by engaging family labour**. While many of the on-the-ground implementations draw on women's groups, care is needed to **avoid undesirable unpaid workloads for farm women**. That means, there might be a clear trade-off between women's agency development and negotiating with the load of unpaid work. Understandably, many of the benefits on the homestead plots may be accessed and controlled by the farm women and the **same should proactively be extended to NF practised on larger pieces of land generating marketable surplus**. We are aware of the complexity of this issue and limit our observation to drawing the attention of implementing agencies.

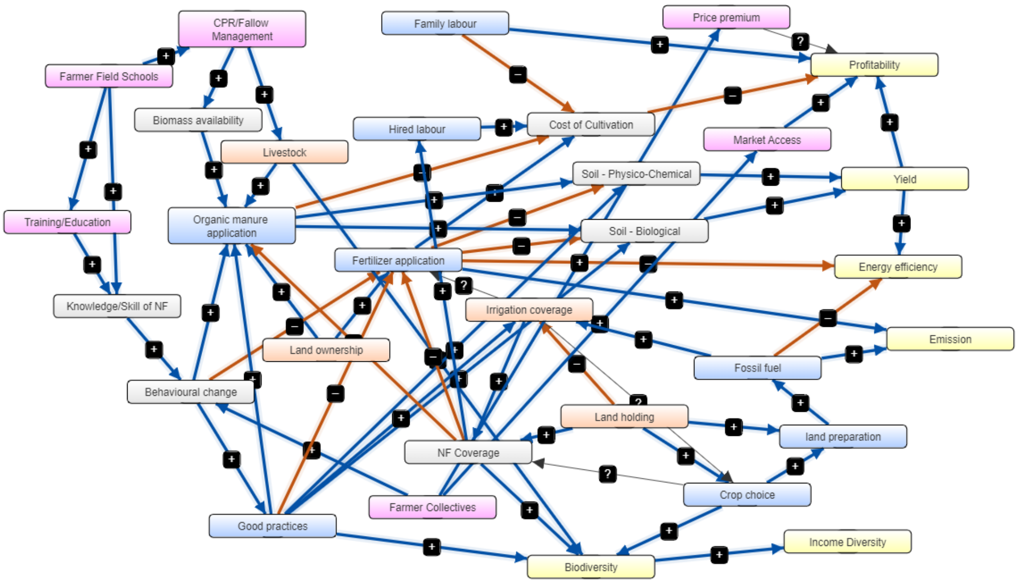
We have found significantly improved energy-related outcomes in the NF. Emission-related outcomes were also better in NF (but not statistically significant). As mentioned earlier, this advantage stems largely from the lower use of synthetic fertilizers and fossil fuels (in irrigation and land preparation). This is countered by management choice (means of land preparation and irrigation), manure application, and yield/biomass production. That means if we intend to maintain better system performance and limit environmental externalities, NF practices must ensure **sustainable means for land preparation and irrigation** with **sustainable intensification** (e.g., legumes in the cropping systems) options to improve yield and profitability. This may not seem immediately important in the short run, but NF champions should not fall into the trap of yield/income obsession like industrial agriculture. We suggest that 'suitable' technological options (e.g., solar power-driven irrigation, rationalized nutrient management) be in place for an NF intervention. Unsupervised **application of organic manure** affects both energetics and emission, and their **close monitoring is required to maintain the environmental advantages** of the NF. Further, appropriate crop choices, preferably **less resource-intensive ones** (e.g., millets, pulses and oilseeds), are to be given due consideration while planning cropping systems for NF. Also, multi-tier cropping or cropping systems producing higher biomass sustainably may be introduced to maintain system efficiency in NF.

Resource interaction in small farms is a key to improved system outcomes (Goswami et al., 2016), and indigenous mechanisms of circularity are observed in many low external input systems. We found only small differences in resource interaction patterns between NF and CF. Although NF, by principle, may not explicitly promote many resource-recycling mechanisms, this is often critical to managing moisture and nutrients in a naturally maintained farm. However, there is a limit to which such endogenous recycling can manage input needs for the crops on natural farms (Smith et al., 2020; Goswami et al., 2020). A fraction of the farms demonstrated unique resource interaction using common property resources, fallow lands, and small livestock, which was otherwise absent among the majority of NFs. We recommend that **appropriate science and technology intervention be sustained by community-level institutions (the farm schools) to revive CPR and fallow land for producing farm inputs (fodder, biopesticides, biomass, fuel).** Recent evidence of agroforestry-assisted natural farming is particularly encouraging (Dinesha et al., 2023).

Innovations in the form of appropriate models of bio-marts may also add circularity in the local agroecosystems. Also, our network study reveals that **paddy fields, cattle and small livestock be given due importance for contriving resource flow pathways** on natural farms to create an optimal impact on the system outcomes.

A majority of farms (~95%) practising NF continued the practice in the next seasons, and most of them have increased the acreage. We observe that the growth is more conspicuous when a farmer scales up NF from homestead land to main crop fields. That is why area expansion is more conspicuous in districts where experimentation started on homestead plots. Nevertheless, we assume that the human capability development in terms of training (by green colleges) and community mobilisation might also have sustained and pushed the practice among a community. But we also observe relatively low coverage of NF in farms (less than ~50% of total land holding) implying a delay in producing significant farming system outcomes, which is more conspicuous when a package for NF is adopted together. We suggest, on a reiterative note, the NF cycle for a region may **commence on homesteads or small plots** (depending on available resources) and then **expand to larger plots or clusters of plots** (on the same field) **until yield and economic advantages are demonstratively established**. Before that, an out-scaling effort ‘may not sustain’ due to supply-side failure, even after collectivisation which is contingent upon great social mobilization.

By amalgamating different pieces of evidence that we could manage, we develop a holistic model to describe the complexity and identify the levers to impact natural farming in the study areas. Drawing on the systems theory used in cognitive mapping (which is otherwise used for eliciting models from diverse stakeholders), we have added the pieces of evidence to link the micro-level context of NF with the system’s outcomes. The conceptual model linking NF with biogeochemical processes is available only recently (Duddigan, et al., 2022), but the mechanism linking micro-level of NF operations with local context and macro realities is not empirically established yet. We summarize the complex dynamics of NF based on our study and literature review (Fig. 4.1) and simulated four possible scenarios that can influence the desirable outcomes emanating from NF (Fig. 4.2).



Total System Component - 31; Total Connections – 61; Density - 0.0655913978
Connection per component - 1.9677419355; Drivers – 5; Receivers – 5;
Highest Centrality – Fertilizer application, Manure application (immediate monitoring points)

Fig. 4.1: Complex system dynamics of Natural Farming in the study areas. Boxes are system elements and lines are causal relationships. Red and blue lines represent a negative and positive relationship between a pair of elements. The relationship for a few pairs is not confirmed (thin black line). The colour of the boxes represents a group of elements – a) White – Intermediate outcomes, b) Saffron – Context, c) Blue – Input and Management, d) Yellow – Outcomes, and e) Pink – System interventions. The diagram is developed using the Mental Modeler platform (Gray et al., 2013).

There are certain micro-level contexts within which the introduction and expansion of NF take shape in a region. These are land holding, tenurial system, irrigation opportunities, livestock ownership, and availability of family labour (family type and size). And most of the

NF interventions aim to result in higher yield, profit, income diversity, biodiversity, energy efficiency and reduced emission (we have not included food or nutrition security, health outcome, climate resilience, risk mitigation etc. in this framework simply because we did not generate enough reliable data to claim so). NF interventions may take the form of training and mass awareness, demonstration through field schools and green colleges, common property resource and fallow land management, and institution building in the form of cooperatives/producer organizations to enhance bargaining power and market access of farmers. The immediate outcomes of such interventions are manifested in the form of farmers' individual and collective behavioural change, thus resulting in the adoption of good practices, reduced synthetic fertilizer use and increased organic manure applications, which impacts the emissions from NF systems. Input and labour management, coupled with crop choice and the decision to use fossil fuel in land preparation and irrigation, affects the cost of cultivation and profitability, and energy efficiency. On the one hand, the said management impacts soil fertility and crop yield. This scheme ideally succeeds in a favourable policy environment that encourages producer-seller conglomerates to facilitate market access and price premiums, payment for ecosystem services, and risk management supports. We avoid adding related macroeconomic, and sectoral policies such as fertilizer subsidies and energy policies here.

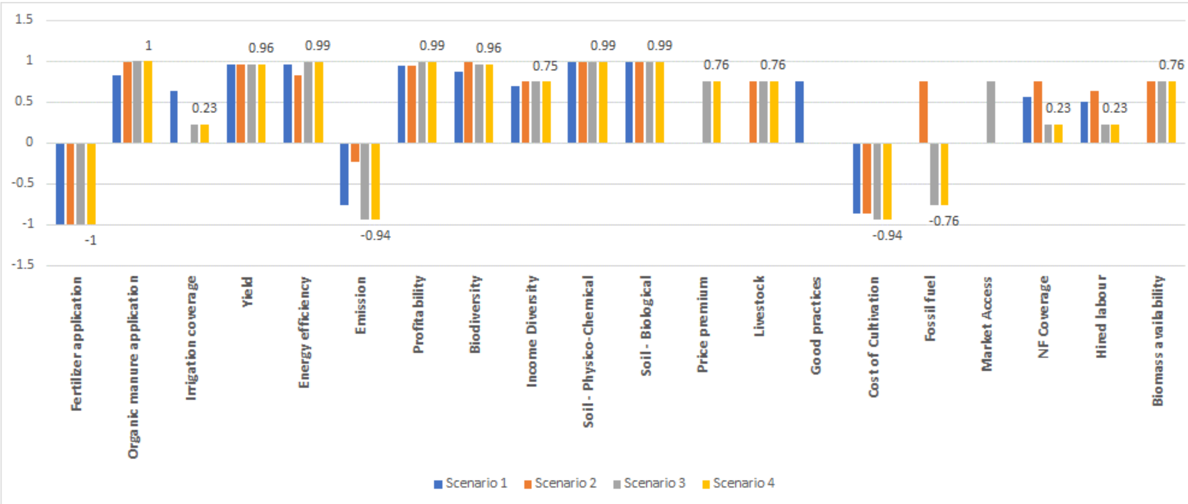


Fig. 4.2: Scenario analysis showing the predicted impact on the system elements under four different scenarios. The X-axis represents the system elements, and Y-axis represents the relative change expected in the given system elements under different scenarios. Values above and below zero suggest positive and negative changes, respectively. Original values of the elements' responses were generated in Mental Modeler (Gray et al., 2013) using the 'scenario analysis' module. The weightage of linkages was binary (presence-1; absence-0).

Scenario 1: Education (knowledge/skill of NF, Training, Behavioural change)

Scenario 2: Scenario 1 + Irrigation, Adoption of good management practices, Land preparation, CPR/Fallow management

Scenario-3: Scenario-2 + Institutional Innovation

Scenario-4: Scenario 3 + Market Access

Simulations run on the abovesaid semi-quantitative model under four distinct scenarios (Figure 4.2) suggest – **educational efforts with appropriate local institutions where behavioural (practice) change is ensured is alone capable of creating a large impact** on the desired systems outcomes under NF. Practice level changes, especially the decision to irrigate and land preparation, improve economic outcomes but reduce energy efficiency and emissions from the NF systems. The addition of institutions like farmer field schools and market access enhances profitability and other parameters also when management operations are energy efficient. This scenario is marginally improved with enhanced market access when reduced cost of cultivation and price premium is assured. This model is just indicative and needs to assign weight to dyadic element relationships based on multistakeholder input. Hence, the interpretations are to be treated with precautions. The high centrality of fertilizer and manure application is also insightful and suggests **sound monitoring to ensure that appropriate input management is taking place** at the ground. The large impact of educational efforts also suggests that close monitoring is done to ensure **knowledge augmentation and behavioural change are warranted by field schools and green colleges**.

The complexity of the NF systems suggests that **targeting of NF** is in place for farms operating under different agroecological locations, with different irrigation coverage, cropping patterns, and socio-cultural and market orientation. A **typology delineation** may be followed by a **resource assay and constraint analysis**. Then only we can engage in a **participatory farm design and on-farm experimentation** with farmers to standardize location-specific NF models.

We agree and argue that an **accounting of the ecosystem services** is a prerequisite for advocating NF to the policymakers. It is difficult and time-consuming to study NF for its extra-normal novelty and put them into appropriate numbers. An objective and factual assessment of systems outcomes in NF are extremely difficult because of the diversity in input sources and farm management practices. Conventional farming, for which most of the financial and environmental assessment practices are standardized, may not apply to NF as such. For example, while accounting for cost and profit, the exact value of locally managed biomass and the magnitude of labour engagement is challenging. When accounting for energy and emission, the equivalence of several non-chemical inputs (seed treating material, liquid manure, biopesticide) is unavailable in the standard literature. Further, the non-standard measurement units of these inputs and dependence on recall data make the assessment prone to systematic error. We have avoided using anecdotal evidence and observations in this report simply because this cannot be measured and generalized for a larger population. **We suggest that an appropriate framework be prepared for accounting ecosystem services in NF based on which record keeping journals may be developed for the farmers in NF projects.** We find this to be a significant reinforcing mechanism to link the demand and supply sides of natural farming.

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Appendix I: Data collection guide

Integrated Rural Development and Management Faculty Centre
Ramakrishna Mission Vivekananda Educational and Research Institute

Assessment of ‘Natural Farms’ (NF) in Selected Areas of Jharkhand

Interview Schedule for Farm-level Data Collection

Consent Form for the Respondent

If you agree to participate in this study, you will be asked to answer some questions on natural farming practices on your farm that you consider harmless to your or your household’s interest. The enumerator will ask questions and visit your farm during or after the interview. He/she may take photographs and location details, observe the farm and measure/examine objects, and collect soil samples with your permission. Parts of the interview may also be audio-recorded if you agree.

There is no explicit and known risk associated with answering to the questions posed by the enumerator. If you feel uncomfortable with any question or feel dissatisfied with the interview process, raise the issue immediately. Your participation in the survey is voluntary and you may quit the interview at any point in time. Quitting the study will not affect your relationship with any supporting agency that serves in your area. You need to spare some time (approximately 60-75 minutes) for the interview. Please know, there is no direct personal benefit associated with your participation in this interview. The outcomes of the study will be used to understand the impact of natural farming in Jharkhand.

The study will maintain anonymity if you wish and the confidentiality of the data will be maintained by the study team. Your identity will not be disclosed in the research report or associated publication/s. In exceptional situations (e.g., publication of a case study) if it is needed to be published, we will give you the opportunity to review and approve any material that is published about you.

You hold the right to ask any questions about this study and the interviewer is bound to answer those questions before, during or after the study. In case of unsatisfactory or further questions about the study, you can contact Dr. Sudarshan Biswas or Dr. Rupak Goswami through telephone at 9903419791/9674954840.

By putting your signature below, you have decided to volunteer as a participant in this study and you have read and/or understood the information provided above.

Respondent’s Name and Signature with date:

Interviewer’s Name and Signature with date

A. Background Information

100.1 Schedule Code: 100.2 Practice natural farming (NF): YES/NO

101. District: 102. Block: 103. Village:

104. Name of the respondent (if willing to disclose):

105. Caste UR ☐ OBC ☐ SC ☐ ST ☐ Others:

106. Gender of the household head: MALE ☐ FEMALE ☐

107. Age of the household head (in years):

108. Experience of farming (in no of years):

109.1 Latitude: 109.2 Longitude: 109.3 Altitude:

110.1 Distance from nearest market (minutes of walking time):

110.2 If new market explored after NF, what is the distance:

111 Distance from nearest metaled road (minutes of walking time):

112. Details of family members, occupation and income

	A	B.	C.	D.	E.	F.	G
Sl. No.	Gender	Age (years)	Education	Primary Occupation	Secondary Occupation	Annual income from D (Rs)	Annual income from E (Rs)
1							
2							
3							
4							
5							
6							
…							

113. House details (where the majority of family members stay); mark with a tick (√)

		Katcha	Pucca
201.1	Floor		
201.2	Wall		
201.3	Roof		

114.1 Started Natural farming in (record the year):

114.2 Area under NF when started (ha):

114.3 Is s/he continuing with NF? YES/NO

114.4 If yes, what is the current area under NF (ha):

B. Farm Particulars, Income-Expenditure

[Record land size in decimal or locally used unit]

201. Number of land parcels (owned):

202. Size of homestead land (own):

203. Size of cultivated land (own):

204. Leased in land:

205. Leased out land:

206. Fallow land:

207. Perceived soil fertility (tick):

A. HIGHLY FERTILE	
B. FERTILE	
C. MODERATELY FERTILE	
D. DEGRADED	

[Collect/record soil test record, if any]

208. Source of irrigation (record the code in the second column):			
	Community – 1; Private – 2; Public – 3 [1]	Number (and irrigated area), wherever applicable [2]	Available for (Number of months in a year) [3]
A. Pond/Dova			
B. Canal			
C. Groundwater			
D. River Lift			
E. Dug well			
F. Others (specify)			

209. Total irrigated area (local unit):

210. Cattle Ownership

	No of adult **[1]**	No of calf / chicks / kid **[2]**
A. Cattle		
B. Goat		
C. Sheep		
D. Poultry		
E. Duck		
F. Others		

211. Income and expenditure (consider both economic products and by-products; consider both self-use and commercial use of farm produce)

Income sources [A]	Amount (Rs)* [B]	Expenditure [C]	Amount (Rs) [D]
1. Crop 1		1. Food Consumption	
2. Crop 2		2. Clothing	
3. Crop 3		3. Fuel	
4. Crop 4		4. Toiletries and cleanliness	
5. Crop 5		5. Transport	
6. Crop 6		6. Electricity	
7.		7. Housing	
8. Cow		8. Healthcare	
9. Buffalo		9. Education	
10. Bullock		10. Festivals/religious activities	
11. Goat		11. Social functions	
12. Pig		12. Interest Payments	
13. Sheep		13. Communication (mobile, data)	
14. Duck		14.	
15. Poultry bird		15. Hired machine for land preparation	
16. Fish		16. Hired machine for harvesting	
17. Fruit 1		17. Irrigation	
18. Fruit 2		18. Seed	
19. Fruit 3		19. Fertilizers	
20.		20. Pesticides	

21. Tree 1		21. Hired labour	
22. Tree 2		22. Transport of farm produce	
23. Tree 3		23. Packaging and storage	
24.		24.	
25. Forest produce		25. Others	
26. Wages (Member 1)			
27. Wages (Member 2)			
28. Business			
29. Salary			
30. Remittances			
31. Others			

* Record market value if consumed by the farm family

212. Source of energy used by farm household (multiple choices allowed):

Electricity ☐ LPG ☐ Kerosene ☐ Biogas ☐ Solar energy ☐ Fuel wood ☐ Others ☐

213. Proportion (0-100) of energy need (as perceived by the respondent) met by renewable sources (Biogas, Solar energy):

C. Cultivation Details, Input and Labour Use

300. Cropping sequence, production and income (record last normal year's data)

Land parcel	Area (dec.) **[300.1 to 300.6]**	Zaid				Kharif				Rabi		
		Crop [A]	Yield (kg) [B]	Market value (Rs.)* [C]	Area [D]	Crop [E]	Yield (kg) [F]	Market value (Rs.) [G]	Area [H]	Crop [I]	Yield (kg) [J]	Market value (Rs.) [K]
1												
2												
3												
4												
5												
…												
Homestead [300.6]		1										
		2										
		3										
		4										
		5										

* Record market value if consumed by the farm family

301. Seed, chemical fertilizer, micronutrient, soil amendments, organic manures, biofertilizer, seed, and pesticide (insecticide, fungicide, herbicide, biopesticide) used during the last normal agricultural year (total volume purchased and expenditure incurred)

		Volume purchased (Kg/ml/g) [1]	Value (Rs.) [2]	Change in recent years (3-5yrs) / after NF, if any	
				Before [3]	After [4]
A	Urea				
B	DAP				
C	SSP				
D	TSP				
E	MoP				
F	N:P:K				
G	Micronutrient 1:				
H	Micronutrient 2:				
I	Micronutrient 3:				
J	Gypsum				
K	Lime				
L	Others 1:				
M	Others 2:				
N	Farm Yard Manure				
O	Cow Dung Manure				
P	Vermicompost				
Q	Plant-based cakes				
R	Others 1:				
S	Others 2:				
T	Liquid Manure 1				
U	Liquid Manure 2				
V	Liquid Manure 3				
W	Seed 1:				
X	Seed 2:				
Y	Seed 3:				
Z	Seed 4:				
AA	Seed 5:				
AB	Seed 6:				
AC	Pesticide 1:				
AD	Pesticide 2:				
AE	Pesticide 3:				
AF	Pesticide 4:				
AG	Pesticide 5:				
AH	Biopesticide:				
AI	Biofertilizer:				

302. Human labour used in farm operations (record data for last year)
[Farm operations include all field operations, transport, storage, value addition, and any related operations of livestock management, farm maintenance, manure/biopesticide preparation, orchard/tree management, etc.]

Operations	Name of the crop(s)	Human Labour (mandays)			
		Hired		Family	
		Male [1]	Female [2]	Male [3]	Female [4]
302.1 Zaid season	a. b. c. d.				
302.2 Kharif season	a. b. c. d.				
302.3 Rabi season	a. b. c. d.				
302.4 Orchard management					
302.5 Livestock care					
302.6 Homestead gardening					
302.7 Bee Keeping					
302.8 Mushroom Cultivation					
302.9 Others (specify)					

D. System Outcomes

401. Adequacy of food production:
[Record the number of months farm produce supports family consumption]

Crops	Months [record the consumption per week] [1]	Support from fair price shop/ ration (per month) [2]	Sold to market (Kg) [3]	Changed after the adoption of NF? [Increased/ Same/ Decreased] [4]	Amount sold to the local market* [5]
A. Paddy					
B. Wheat					
C. Maize					
D. Millet (Maruwa)					
E.					
F. Vegetables					
1.					
2.					
3.					
4.					
…					
G. Milk					
H. Meat					
I. Fish					
J. Egg					
K. Fruits					
L. Oil					
M. Spices					
N. Mushroom					
O. Pulse					
P. Sugar					
Others (specify)					

* Nearest accessible market

402. Membership (of any family member) to of the following organisation/s

Name of Organization [A]	Membership (Member – 1; Portfolio holder – 2) [B]	Benefits of being member [C]
1. SHG		
2. Co-operative		
3. Micro-finance		
4. FPO / FPC		
5. Local NGO		
6. Political party		
7. Panchayat/Self-governing body		
8. Others (specify)		

.

403. Did you take loan for any purpose last year? If YES

Source [A]	Amount [B]	Interest rates [C]	Purpose [D]	Repaid or Not [E]
1.				
2.				

404. Did you avail/take any crop insurance for your grown crops? If YES,

Crop [A]	Area covered [B]	Insurance agency [C]	Premium [D]	Changed in recent years/ after adoption of NF [E]
1.				
2.				

405. Savings and financial assets

	Yes/No [A]	Amount/Sum insured [B]	Changed in recent years/ after adoption of NF [C]
1. Bank account			
2. Savings			
3. Fixed deposits			
4. Life insurance			
5. Health insurance			

406. Whether any family member has migrated in the last three years? (Yes/No) _________

407. If yes, specify the following (consider the last three years)

Family member [A]	Where? (How far) [B]	Period of migration (Months per annum) [C]	Remittance received (Rs per annum) [D]	Changed in recent years/ after adoption of NF [E]
1.				
2.				
3.				

408. Where from have you known or learned about the news/practice of natural farming?

a. Neighbour
b. Fellow farmers (in the same field)
c. Farmers in the neighbouring villages
d. Relatives
e. Farmers in the market/ public place
f. Others

409. Have you shared the knowledge of natural farming with others? If yes, record the numbers

	Shared information [A]	Taught technical knowhow [B]	Shared material [C]	Practice of NF is actually adopted [D]
1. Neighbour				
2. Fellow farmers (in the same field)				
3. Farmers in the neighbouring villages				
4. Relatives				
5. Farmers in the market/ public place				
6. Others				

410. Training received:

410. Have you/your family members received any training on natural farming in the last 3 years? (Yes/No) [consider if the first training motivated the respondent/her family members to attend further training/s]		
Broad theme/ Thematic Area [A]	Name of the institution [B]	Number of days [C]
410.1. 410.2. 410.3. 410.4. …		

411. Access to Extension/Agri-advisory services:

	Number of times in a crop season [A]	Access established/ increased after NF adoption? [B]
1. Grassroots-level extension functionary		
2. Agricultural extension officer		
3. Panchayat member		
4. NGOs		
6. Others		

412. Child Labour (less than 14 years):

412.1. Do your own children participate in farming practices?	YES NO
412.2. Children hired from outside for farm activities?	YES NO

413. Health status of family members:

	Yes=1; No=2 [A]	Changed in recent (3-5) years/ after adoption of NF [B]
413.1. Head of the family*		
413.2. Primary working woman member*		
413.3. Incidence of malnutrition amongst children?	YES/NO	
413.4. Any chronic disease of family member?	YES/NO	

*Options: 5. Very good 4. Good 3. Moderately good 2. Bad 1. Extremely poor

414. Farm investment in the last 2-3 years/ after the adoption of NF (record the details):

	Details [A]	Expenditure (Rs.) [B]
1. Purchase of land		
2. Purchase of farm implements 1		
3. Purchase of farm implements 2		
4. Purchase of farm implements 3		
5. Purchase of large livestock		
6. Purchase of small livestock		

7.	Excavation of WHS		
8.	Soil reclamation		
9.	Plantation		
10.	Building animal house		
11.	Building poultry house		
12.	Others		

E. Biodiversity

501. Plant species diversity on the farm [record the local name and botanical name]

Name of the Plant species	Frequency	Height (m)*	Breadth at * breast height (m)	Use

* Applicable for tree species only

601. CHANGES IN FARMING AND LIVELIHOODS

[Major changes in farm/livelihoods in recent years, especially after the adoption of natural farming (e.g., the past ~3-5 years). Put a '√' in appropriate cell. Consider allow a flexibility in the time frame]

	Increased	Decreased	No Change	Rate against a 4-point scale	Any specific point in time (year) when the change started
	[A]			[B]	[C]
1. Kharif rice production					
2. Rabi rice production					
3. Maize production					
4. Wheat production					
5. Millet (Maruwa) production					
6. Vegetables production					
7. Fruits production					
8. Pulses production					
9. Cash crop					
10. Fishery					
11. Crop failure					
12. Land holding					
13. Land fragmentation					
14. Pond number/size					
15. Irrigation coverage					
16. Soil fertility					
17. Inundation of crop field					
18. No. of Cattle					
19. No. of Goat					
20. No. of Poultry birds					
21. Fodder production					
22. Farm machinery use					

23. Food available months					
24. Marketable surplus					
25. Diversity of farm produce					
26. Diversity in income					
27. Household assets					
28. Mandays generated on the farm					
29. Women's participation in farming					
30. Women's workload					
31. Women's access to farm profit					
32. Input cost					
33. Use of indigenous seed					
34. Access to quality seed					
35. Use of organic manure					
36. Use of inorganic fertilizer					
37. Use of pesticide					
38. Availability of irrigation water					
39. Efficiency of irrigation water use					
40. Cost of cultivation					
41. Farm income					
42. Off-farm income					
43. Off-farm work					
44. Adoption of new technologies					
45. Support of Govt. schemes					
46. Savings					
47. Indebtedness					
48. Financial assets					
49. Access to institutional credit					
50. Migration of family members					
51. Remittance received					
52. Access to market					
53. Local sale of farm produce					
54. Membership to farmers organisations					
55. Membership to SHG					
56. Contact with extension agencies					
57. Expenditure on health					
58. Expenditure on child education					
59. Quality of drinking water					

60. Health of the family members					
61. Yearlong opportunity to work					
62. Yearlong income					
63. Yearlong food availability					
64. Insect pest load					
65. Crop disease load					
66. Weed in the field					
67. Helpful insects in the field					
68. Diversity of plants					
69. Diversity of animals					
70. Soil fertility					
71. Earthworm in the soil					
72. Knowledge of farming					
73. Prestige among the peers					
74. Self-worth as a farmer					
75. Environmental awareness					

*[4-Very high, 3- High, 2-Moderate; 1-Negligible]

F. Case Study Segment

Tell us the story of starting natural farming on this farm. Mention the motivation, information sources, persons involved, capacity building, social learning from fellow farmers etc.

Tell us about the role of local NGOs and other organisations in initiating NF on your farms/in the locality

What do you see distinctly different in your farm (that one would not find in a conventional farm)?

What are the clear advantages of NF as you have experienced?

What are the most critical constraints of NF as per your experience?

How have you marketed your farm produce? What were the challenges?

How have you learned NF from your fellow farmers? How have you shared NF with your fellow farmers?

Is NF good for all kinds of farms/farmers? Who will benefit most from NF? Why?

Will you continue with NF in the future?

701. Crop wise Input-Output details (record for at least one major staple and cash crop)

Name of the crop with variety (staple crop): Season:

Operations/Inputs	Description (implements/ fertilizer/ pesticide etc.) [Tractor/ Power tiller/ Rotavator etc.]+ [1]	Labour required (hours)				Input Quantity (no./ Kg/ gm/ ml/L) [record hours of operation & Fuel consumption] [6]	Input Expenditure in Rs. [7]
		Hired		Family			
		M [2]	F [3]	M [4]	F [5]		
A. Land Preparation (record frequency)							
B. Seed bed prep							
C. Seed							
D. Seed Treatment material							
E. Transplanting							

F. Sowing							
G. Fert App. Basal1							
H. Fert app. Basal2							
I. Fert. App. Basal3							
J. Manure App. Basal1							
K. Manure App. Basal2							
L. Fert App. Topdressing1							
M. Fert App. Topdressing2							
N. Micronutrients (S, Zn, B etc.)							
O. Irrigation							
P. Weeding							
Q. Herbicide application							
R. Pesticide Application							

S. Growth Regulator							
T. Harvesting (including carrying cost)							
U. Threshing							
V. Winnowing							
W. Packaging							
X. Storing							
Y. Marketing [Vehicle type (light/heavy) and carrying capacity; distance from market; frequency of travel]							
Z. Economic output (Kg):						AA. Byproduct (Kg):	
AB. Revenue from economic output (Rs.):						AC. Revenue from byproduct (Rs.):	

+ Record the approx. weight (kg) and life span (years) of the implements / machines [if not sure, record the model of the implement]

702. Name of the crop with variety (cash crop): Season:

Operations/Inputs	Description (implements/ fertilizer/ pesticide etc.) [Tractor/ Power tiller/ Rotavator etc.][+] [1]	Labour required (hours)				Input Quantity (no./ Kg/ gm/ ml/L) [record hours of operation & Fuel consumption] [6]	Input Expenditure in Rs. [7]
		Hired		Family			
		M [2]	F [3]	M [4]	F [5]		

A. Land Preparation (record frequency)							
B. Seed bed prep							
C. Seed							
D. Seed Treatment material							
E. Transplanting							
F. Sowing							
G. Fert App. Basal1							
H. Fert app. Basal2							
I. Fert. App. Basal3							
J. Manure App. Basal1							
K. Manure App. Basal2							

L. Fert App. Topdressing1							
M. Fert App. Topdressing2							
N. Micronutrients (S, Zn, B etc.)							
O. Irrigation							
P. Weeding							
Q. Herbicide application							
R. Pesticide Application							
S. Mulching							
T. Staking							
U. Growth Regulator							
V. Harvesting (including carrying cost)							
W. Threshing							
X. Winnowing							
Y. Packaging							

Z. Storing							
AA. Marketing [Vehicle type (light/heavy) and carrying capacity; distance from market; frequency of travel]							
AB. Economic output (Kg):					AC. Byproduct (Kg):		
AD. Revenue from economic output (Rs.):					AE. Revenue from byproduct (Rs.):		

+ Record the approx. weight (kg) and life span (years) of the implements / machines [if not sure, record the model of the implement]

703. Access to resources by women: (Mention how the resources are accessible to the women). Extent of access/control is represented by number (**1 for least, 5 for most**)

Resources	Access [1]	Control [2]	Control over Benefits (produce/ money) [3]	Changed in recent years/ after adoption of NF (Control over Benefits) [4]
A. Homestead land				
B. Farm land				
C. Water body				
D. Trees				
E. Cattles				
F. Small livestock				
G. Agri-implements				
H. Fallow land				
I. Others (specify)				

704. Best practices-

Sl. No.	Best Practices	Description [A]	Change in recent years (3-5 years)/after NF	
			Adoption Before NF (Yes/No) [B]	Adoption After NF (Yes/No) [C]
1	Raised bed furrow irrigation			
2	Seed Treatment			
3	Seedling treatment			
4	Line sowing			

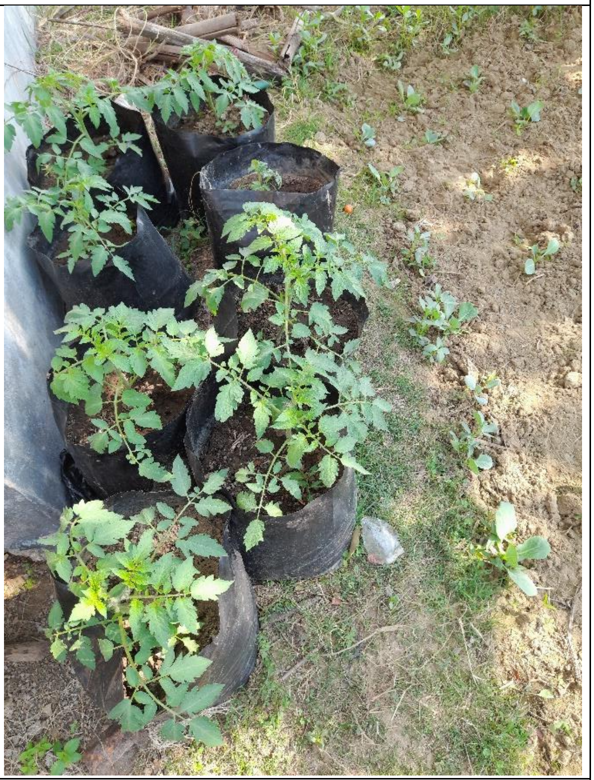
5	Proper spacing			
6	Use of portray			
7	Application of soil amendments e.g., lime, gypsum etc.			
8	Green Manuring			
9	Land shaping			
10	Plantation on bunds			
11	Crop rotation with legume(s)			
12	In situ composting			
13	Mulching			
14	Installation of micro irrigation system (drip, sprinkler etc.)			
15	Preparation and Application of enriched organic liquid manure			
16	Application of biofertilizers			
17	Preparation and application of home-made insecticides/botanicals			
18	Preparation and application of home-made fungicide / bactericides			
19	Preparation of scaffold for creeper crops			
20	Seed production at farm (for own farm requirement)			
21	Mini water harvesting structure at farm land (hapa etc.)			
22	Relay cropping			
23	Bird perch			
24	Use of solar power (e.g., pump)			
25	Hedge cropping			
26	Agro-forestry			
27	Animal house on the pond			
28	Azolla cultivation			
29	Seed storage network			
30	Local sale			
31	Medicinal plants in the farm			
32	Bio-gas plant			
33	Vermicomposting			

705. Farm resource interaction matrix. Record and rate the interaction in four-point scale.
*[4-Very high, 3- High, 2-Moderate; 1-Negligible]

	Rice/staple crop field	Vegetable field	Cattles	Goats	Pig	Poultry	Pond/WHS	Tree	Kitchen	Homestead land	Common Property Resource	Fallow land	Canal	Manuring pit	Others
Rice/Staple crop field															
Vegetable field															
Cattles															
Goats															
Pig															
Poultry															
Pond/WHS															
Tree															
Kitchen															
Homestead land															
Common Property Resource															
Fallow land															
Canal															
Manuring pit															
Others															

706. Draw a resource flow diagram in the farm depicting all possible components. Record the quantity of resource flow between each pair of components whenever possible -

Appendix II - Field Photographs

<table>
<tr><td></td><td></td></tr>
<tr><td>Photograph-1: Cattle holds a central position in natural farming; on average, respondents owned 2-3 cattle in the study areas</td><td>Photograph-2: Small livestock are important but less explored in the practice of natural farming</td></tr>
<tr><td></td><td></td></tr>
<tr><td>Photograph-3: High crop diversity on the homestead plots</td><td>Photograph-4: Innovations on the homestead plot to enhance resilience and nutrition</td></tr>
</table>

Photograph-5: Solar power-driven irrigation can enhance productivity and profitability without conceding environmental benefits on natural farms

Photograph-6: Mulching saves in-situ soil moisture; however, there is debate concerning the viability of synthetic mulching material

Photograph-7: Crop diversity enhances biomass production alongside higher income and nutrition

Photograph-8: Azolla unit in a farmer field at Hazaribagh: endogenous supply of plant nutrient is critical for the success of natural farming

Photograph-9: Multitier azolla culture at Morabadi KVK

Photograph-10: Straw mulching with heavy log to combat strong wind – Morabadi KVK

Photograph-11: Agroforestry as a source of biomass and fodder (Divyayan KVK)

Photograph-12: Organic inputs prepared on the farm (Divyayan KVK)

Photograph-13: Farmer Producer Organizations can help farmer achieve scale for their farm produce (Giridih)

Photograph-14: Producer cluster has played a critical role in farmers' knowledge building and its conversion to on-farm actions (Chanda, Hazaribagh)

Photograph-15: Geotagging of plots (Giridih)

Photograph-16: Rhizospheric soil collection (Giridih)

Appendix III: Soil physicochemical properties recorded for individual plots

Sample code*	Lab. Code	pH	EC (mS/cm)	Org. C (%)	Avl. N (kg/ha)	Avl. P_2O_5 (kg/ha)	Avl. K_2O (kg/ha)	Zn (ppm)	Cu (ppm)	Fe (ppm)	Mn (ppm)
D3-EXP	P/1210	6.40	0.24	2.13	338.70	917.70	392.2	2.96	1.54	54.68	39.78
HC2-EXP	P/1211	6.63	0.49	1.59	338.70	326.10	318.5	2.01	1.60	24.57	25.19
HC3-EXP	P/1212	6.81	0.73	1.78	276.00	444.30	360.5	2.45	1.99	22.00	23.17
HU4-Control II	P/1213	5.12	0.80	1.17	338.70	381.50	224.6	2.18	1.08	61.07	38.77
HC1-EXP	P/1214	6.26	0.79	1.51	297.90	554.70	580.1	2.35	1.65	17.63	22.78
KN2-Control	P/1215	3.87	0.26	.59	285.40	54.50	274.6	0.55	0.56	9.98	35.02
HU5-EXP	P/1216	4.30	0.92	1.02	304.20	383.80	256.4	2.06	1.34	102.02	60.68
HC4-EXP	P/1217	5.63	0.70	2.01	241.50	145.50	1391.0	1.55	3.88	144.30	45.94
KN3-EXP	P/1218	5.81	0.22	1.25	185.00	115.90	330.8	2.87	1.67	22.85	30.34
KA3-EXP	P/1219	4.70	0.23	.67	250.90	297.00	463.5	1.18	1.08	26.36	45.55
KN4-EXP	P/1220	4.21	0.13	.63	294.80	45.70	339.5	0.72	0.77	10.22	34.01
HU2-EXP	P/1221	6.19	1.14	1.86	288.50	439.20	1091.6	2.97	2.25	20.20	22.62
HC6-Control	P/1222	6.27	0.72	.94	185.00	479.00	237.5	3.03	1.22	13.96	28.00
KVK-2	P/1223	5.45	1.15	2.36	338.70	469.30	170.0	3.08	5.12	303.42	36.82
KA2-Control	P/1224	5.13	0.15	.63	297.90	123.30	160.7	1.17	0.82	22.39	31.36
HU3-Control I	P/1225	6.39	2.60	1.90	304.20	1023.00	1833.6	3.01	3.01	21.76	28.39
G3-EXP	P/1226	4.65	0.19	.94	332.40	53.60	92.1	1.09	2.13	114.58	59.75
GT4-Control	P/1227	4.39	0.10	1.55	326.10	61.40	95.8	0.87	3.69	212.24	29.33
KA4-EXP	P/1228	4.75	0.17	.82	294.80	162.60	275.7	0.98	0.99	40.56	45.40
KVK-3	P/1229	6.41	1..53	3.32	232.10	1529.20	1172.2	3.16	4.83	42.51	26.52
D2-EXP	P/1230	4.37	0.27	1.40	244.60	213.80	349.3	1.49	2.86	134.47	21.45
GMI-EXP	P/1231	5.05	0.19	.86	250.90	80.40	359.9	2.82	0.97	14.59	28.31
GT2-EXP	P/1232	5.42	0.12	.94	263.40	81.80	319.6	1.61	0.65	14.51	31.36
HUI-EXP	P/1233	6.55	0.91	2.63	410.80	633.20	1426.1	3.07	2.24	15.13	15.13
HC5-Control	P/1234	6.16	0.23	.20	332.40	422.60	139.6	1.11	0.57	14.90	24.96
KAI-EXP	P/1235	5.99	0.15	.73	244.60	80.40	265.3	2.23	1.17	21.92	19.11
DI-EXP	P/1236	4.71	0.20	1.13	197.60	118.70	448.1	1.78	3.41	138.53	29.41
KVK-1	P/1237	6.54	0.50	2.30	200.70	1185.60	2122.7	3.07	4.01	99.76	40.79
GH3-EXP	P/1238	3.85	0.09	.53	213.20	36.00	192.2	2.50	0.68	21.14	30.19
D4-Control	P/1239	4.44	0.37	.93	266.60	248.00	563.0	2.12	2.74	187.20	27.85
KNI-EXP	P/1240	3.92	0.13	.40	200.70	29.10	234.8	0.81	0.55	13.42	28.63
G2-Control	P/1241	4.52	0.17	.53	163.10	53.10	273.0	1.49	0.78	22.39	56.08
GT3-EXP	P/1242	5.31	0.17	.48	254.00	48.00	242.3	1.91	0.53	14.35	28.08
G3-Control	P/1243	3.93	0.14	1.01	203.80	46.60	97.3	1.00	3.11	151.09	30.65
GM2-EXP	P/1244	4.14	0.10	.44	291.60	39.30	203.6	1.72	0.90	34.40	32.53
GT3-Control	P/1245	4.79	0.40	.53	269.70	48.00	553.9	1.36	0.71	19.03	36.19

* D-East Giridih, G-Central Giridih, H- Hazaribagh, K-Khunti; second letters indicate specific villages

Appendix IV: Soil microorganism counts recorded in individual plots

Sample code	Crop rotation	Total bacterial count (X10^9)	Total Actinomycetes count (X10^5)	Total fungal count (X10^3)
D3-EXP	Vegetables	49.00	500.00	61.00
HC2-EXP	Paddy	76.33	60.67	47.33
HC3-EXP	Crop cafeteria	170.00	60.67	50.00
HU4-Control II	Potato	122.33	123.67	105.00
HC1-EXP	Fallow-Pigeon pea-Papaya	103.33	346.67	55.00
KN2-Control	Fallow-Fallow-Wheat	236.00	54.00	26.33
HU5-EXP	Mung-Fallow-Potato	370.67	71.33	108.00
HC4-EXP	Okra-Paddy	366.33	259.33	103.00
KN3-EXP	Fallow-Fallow-Chilli	1266.67	83.00	50.00
KA3-EXP	Fallow-Paddy	40.33	50.67	55.67
KN4-EXP	Niger	142.00	11.00	21.67
HU2-EXP	Ghangra-Finger millet	150.00	99.00	77.33
HC6-Control	Fallow-Kurthi-Potato	89.67	75.33	132.67
KVK-2	Fallow-Paddy-Fallow	496.00	1574.67	85.00
KA2-Control	Fallow-Fallow-Tomato	914.67	215.00	19.67
HU3-Control I	Fallow-Maize	1216.00	80.67	42.33
G3-EXP	Water melon-Guartali	65.00	33.67	26.67
GT4-Control	Bean-Chilli	864.67	68.67	37.00
KA4-EXP	Tomato-Finger millet	36.67	63.67	22.00
KVK-3	Urad-Tomato-Bean	52.33	131.00	38.67
D2-EXP	Chilli-Finger millet	340.00	42.67	30.67
GMI-EXP	Finger millet	101.00	71.33	26.33
GT2-EXP	Finger millet-Spices	153.33	41.33	33.33
HUI-EXP	French bean	13.00	95.67	93.67
HC5-Control	Okra-Garden Pea	191.00	69.33	32.67
KAI-EXP	Brinjal-Tomato-Bokla	97.33	76.00	35.00
DI-EXP	Okra-Maize-Potato	46.00	86.67	37.00
KVK-1	Potato	14.67	116.33	123.00
GH3-EXP	Potato-Wheat	1550.00	107.00	38.67
D4-Control	Potato-Wheat	1384.00	56.33	66.67
KNI-EXP	Veg-Maize-Veg	17.67	59.33	16.67
G2-Control	Veg-Maize-Cabbage	108.67	79.67	55.33
GT3-EXP	Cauliflower-Fallow-EFY/Bitter gourd/Brinjal	586.67	48.00	22.00
G3-Control	Ng-Ng	55.33	65.00	37.00
GM2-EXP	Veg-Maize-Potato	58.00	204.33	43.67
GT3-Control	Fallow-Paddy-Fallow	194.67	120.00	24.00

Selected Case Studies

Case Study – 1

This study delves into the inspiring story of Farmer A - a 24-year-old resident of the beautiful village of Kalamati in the Khunti district of Jharkhand. Following the approach of natural farming, the farmer prioritizes ecological balance and limits the use of external inputs. Through observation and an interview with the farmer, we were able to witness their remarkable farming methods, accomplishments, and the obstacles they faced. We also studied the impact of their practices on the environment and community. Our survey of the local community revealed their admiration for natural farming and its positive effects. This study delves into the inspiring story of Farmer A - a 24-year-old resident of the beautiful village of Kalamati in the Khunti district of Jharkhand. Following the approach of natural farming, the farmer prioritizes ecological balance and limits the use of external inputs. Through observation and an interview with the farmer, we were able to witness their remarkable farming methods, accomplishments, and the obstacles they faced. We also studied the impact of their practices on the environment and community. Our survey of the local community revealed their admiration for natural farming and its positive effects.

Farmer A utilized a natural farming approach, which involved several methods such as non-chemical fertilization, bio-pest management, crop diversity, water conservation, and indigenous seeds. He used organic compost, green manure, and crop residues to enrich the soil with essential nutrients, and botanical extracts like Dashparni and neem-based products to control pests and diseases. To enhance biodiversity and reduce the risk of pests and diseases, he practised intercropping and crop rotation. He also conserved soil moisture for a long period of time by utilizing mulching techniques and cultivated indigenous and traditional crop varieties to preserve local genetic diversity.

However, Farmer A faced several challenges such as initial scepticism from fellow farmers who were accustomed to conventional farming practices, a lack of knowledge and training that required a shift in mindset and skills, and finding markets for organic produce due to limited local demand and awareness. Despite these challenges, his natural farming approach led to improved soil health, reduced costs, increased biodiversity, and community recognition. Moreover, his farming practices minimized chemical pollution in the area by avoiding synthetic fertilizers and pesticides, sparked interest in sustainable agriculture among neighbouring farmers, and contributed to climate resilience by preserving biodiversity and enhancing soil health.

In conclusion, Farmer A'' experiences as a natural farmer in Kalamati highlight the potential of sustainable agriculture to enhance livelihoods, conserve the environment, and improve food security. His methods can serve as a blueprint for other farmers in the area and beyond, encouraging a shift towards more environmentally friendly farming practices.

Case Study – 2

Anshu Devi's (name changed) story of natural farming is truly inspiring. A farmer from Arguri village in Jharkhand, she has implemented natural farming practices on her farm that have brought about remarkable improvements. She uses cow dung manure and organic inputs for crop production and relies on organic alternatives like Neemastra and Agniastra to control pests. Thanks to her training and knowledge of manure preparation, crop sowing patterns, and drip irrigation techniques, she has become an active member of the Farmers’ Field School in her village, sharing her expertise with others. Anshu cultivates paddy and watermelon on her farm, using a high-yielding paddy variety and a drip irrigation system for watermelon. Her farm generates an impressive annual income of Rs. 280,000.

Anshu thinks that by enhancing soil fertility, we can improve crop yields. This can be achieved by replacing chemical fertilizers and pesticides with organic inputs like *Beejamrit*, *Jeevamrit*, vermicompost, NADEP compost, *Matka khad*, and *Panchagavya*. Anshu observed that her practices not only eliminate the need for harmful chemicals but also reduce cultivation and input costs. Additionally, implementing drip irrigation can improve irrigation efficiency thus increasing crop yields.

Anshu enjoyed varying degrees of access and control over different farm resources, and it suggests that women generally have a higher level of access and control over trees, cattle, and small livestock compared to other resources like agri-implements and waterbodies.

The case study of Anshu Devi highlights the advantages of natural farming very clearly – this includes better soil fertility, higher crop yields, and less dependence on chemical substances. Her decision to use sustainable practices is a great example of how ecological farming can benefit farmers and how women can be at the forefront of transformative decision-making. By sharing her experience, Anshu encouraged other farmers to adopt natural farming methods, especially the women farmers operating on small farms.

Case Study – 3

Meet Somra Tude (name cganged), a 45-year-old man from Dhanudih village in Jharkhand, India. He hails from a family of farmers who have been practicing agriculture for generations. Dhanudih, his rural community, lies at Lat: 22.5702189328148960 and Long: 85.966454688459630. In 2018, Purnachandra discovered natural farming through fellow farmers and decided to learn more about it. He joined the Center of World Solidarity (CWS), an NGO that supports organic farming techniques, and received valuable guidance and assistance to help him kickstart his journey into natural farming.

Somra's natural farm is distinguished from conventional farms by its unique features and practices. The farm is diverse and includes a kitchen garden where a variety of vegetables are grown for household consumption, promoting self-sufficiency and a healthy diet. Purnachandra Tue owns 4 goats, 45 sheep, and 60 poultry, which contribute to the overall sustainability of his farming system by providing manure and helping in nutrient cycling. The farm also cultivates medicinal plants such as Neem, Tulsi, and Ashwagandha, which have medicinal value and help maintain ecological balance and biodiversity. Fruit trees, such as Mango, Jackfruit, Tamarind, and Jackfruit, are also integrated into the farm, providing a diverse range of products and enhancing the farm's aesthetic appeal. Somra maintains a vermicompost pit, which serves as a source of nutrient-rich organic fertilizer for his crops, enhancing soil fertility and improving crop yields. He also cultivates azolla, a nitrogen-fixing aquatic fern, in a dedicated tank, reducing the need for synthetic fertilizers. Finally, he uses a solar pump for irrigation, demonstrating his commitment to sustainable energy practices and reducing reliance on fossil fuels.

Somra has observed that his farm's soil has become more fertile and softer due to the implementation of natural farming techniques. As a result, the quality of his produce has improved, leading to better taste and nutritional benefits. By switching to natural farming practices, Somra has considerably reduced his expenses on costly chemical fertilizers and pesticides. Instead, he now relies on locally available natural resources and homemade organic inputs, such as Jivamrita, vermicompost, and natural insecticides. This has helped him save costs and improve profitability. Additionally, intercropping and diversifying his farm produce has enabled him to maximize yields and generate higher income, resulting in increased revenue.

Somra has encountered obstacles and limitations when promoting his organic produce, despite its many advantages. The absence of a specialized market for organic items in his locality presents a major obstacle. Consequently, he was forced to sell his organic produce in the regular market, where he did not receive a higher price. Nevertheless, Somra maintains a positive outlook on natural farming and intends to keep practicing it in the future.

However, Somra faces challenges in marketing his organic produce due to the lack of a dedicated market in his area. Despite this, he remains optimistic about natural farming and is determined to continue practicing it in the future.

The case of Somra Tudu demonstrates the multiple benefits of natural farming on a farmer's life. Through the use of natural farming methods, he has seen an improvement in soil quality, a decrease in expenses, and an increase in earnings. Nevertheless, the lack of a suitable market for organic products remains a challenge for him and his fellow farmers. Creating a specialized market for organic goods would allow farmers to receive fair compensation for their produce and encourage the adoption of sustainable farming techniques.