Why are farmers in South India shifting from conventional 'Green Revolution' agriculture to natural farming? A mixed-methods study

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ABSTRACT

Introduction: The Green Revolution contributed to significant increases in crop production and yield in India. However, it also resulted in negative social and environmental consequences. In response, alternative farming practices have emerged which are based on agroecological principles, such as natural farming. In the recent years government policies at state and national level are also promoting it. However, its adoption by farmers to date has been limited and uneven. The aim of this exploratory sequential mixed-methods study was to understand barriers and facilitators involved in transitioning to natural farming in India.

Methods: A sequential exploratory design was used. Qualitative Focus Group Discussions (FGDs) were conducted in six villages across Anakapalli and Visakhapatnam districts of Andhra Pradesh from March to May 2023. FGD transcripts were coded and analysed using a constant comparative method. Subsequently a questionnaire was developed based on the FGD findings and administered to the head of 1126 households across 82 villages in four districts in Andhra Pradesh from October to November 2023. Given the exploratory nature of this work, no formal statistical testing of the quantitative data was conducted. Instead, questionnaire results were summarized descriptively.

Results: Eleven FGDs were conducted followed by a questionnaire administered to 1126 households. The FGDs revealed that health concerns were a primary motivator for farmers to adopt natural farming, while crops' yield penalties were a major deterrent. In the quantitative phase, household health remained a strong motivator to shift to natural farming. Natural farming practitioners also highlighted the role of Internal Community Resource Persons (iCRPs) (21.3%) as vital for knowledge transfer and support. Both natural farming practitioners and conventional farmers emphasized the need for certified seeds supply (14.4%) and input support (9.3%) to ensure access to inputs. However, different farmer groups had varying needs: conventional

farmers prioritized marketing support and non-pesticide management (NPM) shops, while natural farming practitioners emphasized the importance of infrastructure development and knowledge enhancement for long-term sustainability.

Conclusion: The study highlights the importance of understanding the diverse motivations of farmers to adopt natural farming. Tailoring policies to address the specific needs of each group—whether conventional or natural farmers—can likely facilitate a smoother transition to natural farming and improved adoption rates.

INTRODUCTION

The period between post-independence India and the 1960s in India was a time of food insecurity [1]. The introduction of high-yielding crop varieties in the mid-1960s offered a solution, and gained widespread acceptance among farmers in India, particularly those with assured irrigation facilities, together with other 'Green Revolution' technologies such as application of synthetic fertilizers and pesticides [2–4]. The effects were transformative—resulting in significant improvements in crop yields, greater food availability per capita, increases in farmers' income, and a noticeable decline in undernutrition [5], although these benefits have not been shared equally across agrarian populations in India; larger farmers have benefited more [2].

The benefits of the Green Revolution have come with a cost in terms of environmental degradation (both acute and chronic poisoning from pesticides) [5–9]. The intensive use of pesticides and fertilizers has polluted water bodies and led to soil degradation [10] and biodiversity loss [11,12]. The focus on water-intensive crops has strained already scarce water resources [13]. Moreover, the agri-food system is responsible for 33% of greenhouse gas emissions in India [14], and thus plays an important role in the net zero by 2070 transition [15]. Further, adverse climatic events add to the worsening of agricultural systems [16].

In recent years, yields in India have stagnated [17] while the costs of cultivation, particularly labour and chemical fertilizers and pesticides, have increased [18], resulting in debt and financial distress among agricultural households. In this context, sustainable farming approaches such as natural farming have emerged as a potential solution. To date, evaluations of natural farming in India have focused on impacts – for example, on yield [19–21], soil health [19], pesticide use [22], and income[23,24]. Few have evaluated the process of adopting natural farming from the perspective of farmers [9], particularly the barriers and facilitators to adoption. One previous evaluation found that the major barriers to adopting natural farming were poor availability of bio-inputs, infrastructure support, lack of information, and yield penalty during the

initial years of adoption [9]. Beyond natural farming, the global literature on farmers' adoption of sustainable farming practices suggests that agricultural extension services and training, soil quality, access to irrigation and credit, as well as farmers' educational attainment and income, are important facilitators of adoption of sustainable farming practices [25].

The aim of this study was to understand the barriers and facilitators involved in adopting sustainable farming practices as part of a largescale government program known as the Andhra Pradesh Community-managed Natural Farming (APCNF) program [formerly known as Zero Budget Natural Farming (ZBNF)] [26]. APCNF is being implemented by Rythu Sadhikara Samstha (RySS), a not-for-profit company established by the Department of Agriculture, Government of Andhra Pradesh. Launched in the year 2016, the program aims to convert all 6 million farmers in the state to natural farming; yet just 1 million have started to adopt some APCNF practices after nearly a decade of program implementation [26]. Findings of this study should therefore provide valuable insights into the barriers limiting farmers' ability to adopt APCNF practices that may require solutions, as well as facilitators of adoption that require further support.

METHODS

Study setting

Andhra Pradesh is a south Indian state, ranked 7th and 10th in terms of its land area (8.4% of India's land area) and state population (7.1% of India's total population), respectively [27]. More than half (60%) of the total population of Andhra Pradesh is dependent on agriculture and allied activities [28]. Declining crop yields, increased farm-related debt burden, dwindling agricultural incomes and rising farmer distress are some of the reasons that the state government has started to explore alternative farming methods [29]. Initially, techniques such as integrated pest management and non-pesticide management (NPM) were introduced [30]; these evolved into what is today the APCNF program. The APCNF program was initiated in 2016 ("Phase 1") and had reached 3730 villages as of 2021-22 [31].

For the qualitative phase of this study, six villages from a total of 37 Phase-1 APCNF villages were randomly selected from the erstwhile Visakhapatnam district (Visakhapatnam district was divided into Visakhapatnam, Anakapalli and Alluri Seetha Ramaraju districts in the year 2022). Of the six villages, five villages fell within the Anakapalli district, and one village fell under the Visakhapatnam district. For the quantitative phase of this study, 82 villages across four districts (Anakapalli, Visakhapatnam, Kurnool and Nandyal, (**Figure 1**) were randomly selected in 2022 from a list of villages that had not yet received the APCNF program to participate in a larger study, the Co-Benefits of Large-Scale Organic Farming On Human Health (BLOOM) study [32]. Briefly, the BLOOM study is a randomized controlled trial designed to evaluate whether a government-led agroecology initiative can lower pesticide exposure and enhance dietary diversity among agricultural households.

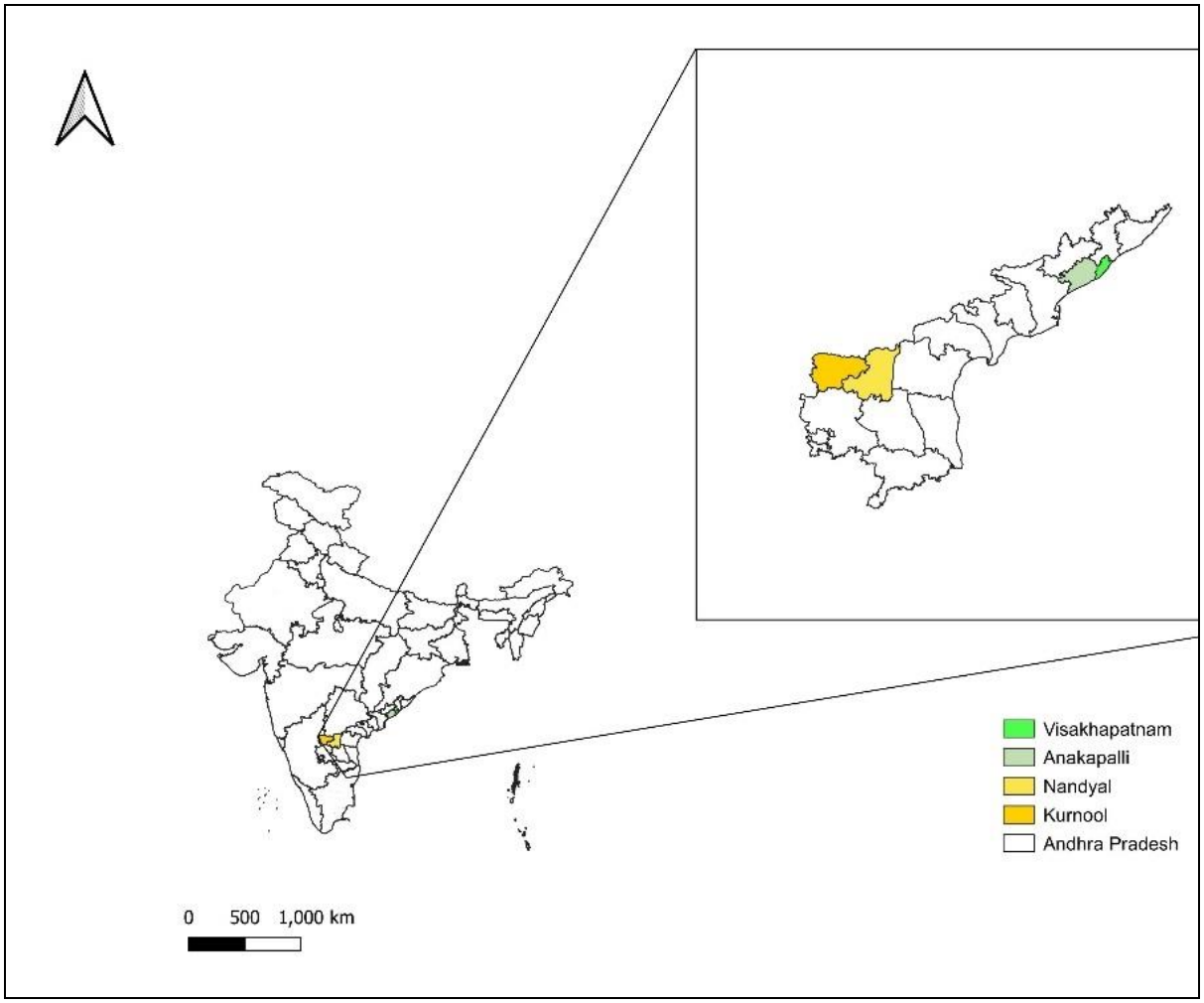

Figure 1: Map showing the districts in Andhra Pradesh represented in this study.

Qualitative data collection

Farmers from each of the six villages were invited to participate in a focus group discussion (FGD) through interactions with village-level stakeholders. The aim was to conduct a total of 12 FGDs, two in each of the six villages. One FGD per village was conducted with natural farming practitioners, while the other FGD was with conventional farmers. A typical FGD comprised of both men and women, with an average group size of 10-12 farmers.

FGDs were led by a trained interviewer (YB, Principal Investigator of the study) in a designated private space within the village in the participants' native language (Telugu). Prior to the start of the FGD, YB introduced himself as a researcher, and clarified his positionality with respect to RySS, i.e. that he was previously employed by RySS but was now working for the BLOOM study, which is independent of RySS. Along with YB, a Data Collector and Field Supervisor from the BLOOM study were present.

Before the start of the FGD, participants were asked to complete a brief paper-based questionnaire that included standard questions on socio-demographics (Additional File 1). A discussion guide was used to facilitate the FGD and included questions on current farming practices, alternative farming practices such as organic farming and natural farming, and motivations and challenges of adopting alternative farming practices (Additional File 2). Specific questions were asked regarding income, soil quality, availability of inputs and trained labor, water requirements, family health, and government policy. Each FGD lasted approximately 25-30 minutes. The FDGs were conducted from March to May 2023, a period with limited agricultural activity to enable greater farmer participation.

The qualitative phase of this study was approved by the Institutional Review Board of the Public Health Foundation of India (Ref No: TRC – IEC 502/ 23) and the Human Ethical Review Committee of the University of Edinburgh (Ref No: HERC_703_21). Written informed consent was obtained from all participants, including for the audio recording of the FGDs.

Qualitative data analysis

FGDs were transcribed and uploaded to Dedoose software version 7.0.23 [33]. In the first pass, YB analyzed the transcripts in Telugu, for emergent themes and drafted a codebook. Then, YB and LMJ reviewed the draft codebook, and it was updated before YB formally coded all transcripts. Coding reports were exported from Dedoose and analyzed using a constant comparative method. Representative quotes for each theme were translated into English by YB.

Quantitative data collection

Based on the results of this analysis, a quantitative questionnaire was developed to capture the barriers and facilitators to adopting natural farming practices. Besides the demographic characteristics of the participants, household agricultural practices, facilitators to shift to natural farming, and barriers that limit the uptake were also collected. The quantitative questionnaire (Additional File 3) was administered to the participants of the BLOOM study [32] during the months of October and November 2023. This was approximately 5 months after the APCNF training had started in the 42 BLOOM villages randomized to receive the intervention. The questionnaire was administered by trained data collectors, to the adult member (aged ≥18 years of age), who were actively engaged in agriculture and were responsible for making farm-related decisions.

Along with the questions on the factors influencing natural farming adoption, questions on what other factors might have facilitated natural farming uptake were also asked. Data on influences were collected only from farmers who reported adopting natural farming on some of their land. Data on barriers were gathered from farmers who reported not adopting natural farming (i.e., conventional farmers). Questions on what might facilitate farmers' transition to natural farming were collected from all participants. Based on their level of engagement in agricultural activities, participants were categorized into three groups: (i) solely farmers, (ii) those who were both farmers and agricultural laborers, and (iii) exclusively agricultural laborers. The questionnaire took approximately 10 minutes to complete.

The quantitative phase of this study was approved by the Human Ethical Review Committee of the University of Edinburgh (Ref No: HERC_703_21) and Ashoka University (HREC No. AUHREC/10062023/meeting2/002-6).

Quantitative data analysis

Quantitative data were analyzed using R software version 4.3.2. Descriptive statistics were used to summarize characteristics of farmers, natural farming practices adopted, motivations for adopting natural farming, barriers to adopting natural farming among conventional farmers, and perceived facilitators of natural farming adoption. Given the small sample size of farmers adopting natural farming in this sample, we were not able to conduct statistical testing for differences by factors such as crop cultivated or farm size.

RESULTS

Qualitative phase

Eleven FGDs were conducted across six villages. In one village, only a conventional farmer FGD was conducted given difficulties in mobilizing farmers practicing natural farming. A total of 69 natural farming practitioners and 56 conventional farmers participated in the FGDs (**Table 1**). In total, 64 men and 61 women participated. The average age was 51 years for men, and 41 years for women. Farmers had been engaged in agriculture, on average, for a period of 24 years. However, the time involved in natural farming was, on average, 4.5 years. Natural farmers tended to be younger, more educated and own slightly more land compared to conventional farmers.

Table 1: Characteristics of farmers who participated in focus group discussions on barriers and facilitators to adopting natural farming practices in Visakhapatnam and Anakapalli districts of Andhra Pradesh, India (2023).

	Overall (n=125)	**Natural farming**	**Conventional farmers** (n=56)

		practitioners (n=69)	
Gender			
Men	64	46% (32)	57% (32)
Women	61	54% (37)	43% (24)
Age (years)			
Men	51 (64)	49 (32)	52 (32)
Women	41 (61)	39 (37)	44 (24)
Education			
Illiterate	31% (39)	25% (17)	39% (22)
Primary school	22% (28)	25% (17)	20% (16)
High school	30% (37)	30% (21)	29% (11)
Intermediate	12% (15)	14% (10)	9% (5)
Graduate	5% (6)	6% (4)	4% (2)
Land holding (acres)		1.6 (1.2)	1.2 (0.8)
Time engaged in agriculture (years)		23 (13)	27 (15)
Time engaged in natural farming (years)	N/A	4.5 (2.5)	N/A
Values are (SD) or (%) n.			

Three major themes and nine sub-themes were identified.

Theme 1: Improvement in human and soil health as a major motivation for shifting to natural farming.

Sub theme 1a: Improvements in health of members of the farming households

Health concerns were one of the primary reasons households reported practicing natural farming. For example, one participant (natural farming practitioner, female, 45 years old, 2.0 acres) said: *"…there are differences in the disease profile. Today, women are undergoing too many*

operations and experiencing a higher disease burden. However, previously, people did not experience many diseases. They consumed naturally farmed food. They used to mill it and consume it. But this generation does not even know how to cook pearl millets." Likewise, a conventional farmer (male, 34 years old, 0.50 acres) said *"In previous generations, households used to cultivate food using natural farming and used to be healthy. But now we are consuming food cultivated using chemical methods. Hence, we are frequently visiting the doctor."*

Of importance was the health impact on future generations of the family. For example, a participant (natural farming practitioner, female, 35 years old, 0.5 acres) said: *"When the children consume chemical foods, they frequently experience fatigue. However, that is not the case when they consume naturally farmed foods. Now they are healthy*."

Participants also reported a link between agro-chemical use and healthcare expenditures. For example, a participant (natural farming practitioner, male, 50 years old, 5 acres) said: *"While applying fertilizers or spraying pesticides we experience headache and dizziness, because of which the health expenditure is more."*

Sub theme 1b: Improvements in soil health

Soil health emerged as an important contributor to a household's decisions to adopt natural farming practices. Improved soil porosity was observed by natural farming practitioners, which in turn influenced the soil moisture content and water holding capacity. A participant (natural farming practitioner, male, 51 years old, 5 acres) said, *"since the soils have become hard, the rainwater runs off, without being absorbed by the soil. However, with natural farming methods, the earthworms make the soil porous, making it suitable for water absorption. Even when the lands do not experience rain for a longer duration, the moisture holds the plants."*

Similarly, another participant (natural farming practitioner, male, 50 years old, 3 acres) said: "covering *the land with green cover all throughout the year will enhance the soil moisture content. This will help reduce the irrigation requirement. Even if the irrigation facility is delayed by*

15 days, even then the plant can withstand the water stressed condition. That's the difference between a chemical plot and naturally farmed plot."

Natural farming practitioners attributed increased yields with improvements in soil health. For example, a farmer (natural farming practitioner, male, 48 years old, 2 acres) said *"Because of natural farming, the yield percentage has improved. Rice yields have improved. The same is experienced in cashew cultivation with natural farming methods. Previously, I used to get 2 bags of cashews, whereas now I get 4-5 bags. I feel these yield differences are the outcome of improvements in soil fertility".*

Conventional farmers also believed that practicing natural farming would lead to improvements in soil health. A conventional farmer (male, 55 years old, 0.5 acre) referring to a fellow natural farming practitioner said that *"See he adds manure to the soil and does line sowing in 0.4-0.5 acres he has. He gets good yield and the same is evident in the yield of peas as well. By adding manure and natural farming techniques, the soil is only going to improve and nothing else happens. It's only because we can't afford to prepare the land is what leads to non-adoption."* While both conventional farmers and natural farming practitioners are aware of the improvements in soil health, other factors also influence the uptake of natural farming.

Sub theme 1c: Improvements in crop health

While improvements in crop health were not reported across all the sites where FGDs were conducted, a village that experienced repeated cyclones observed that crops on naturally farmed plots were more resilient. A farmer (natural farming practitioner, female, 33 years old, 1 acre) said *"When we experience cyclonic storms or heavy rainfall, the ability of the plants to withstand such shocks has improved. Whereas the chemical crops are giving up."*

Theme 2: Decisions involving economic value

Sub theme 2a: Farm investments

Large- and medium-scale farmers were incentivized by the perceived reduction in input costs from natural farming whereas small scale farmers were deterred by perceived increases in labor costs from natural farming. A farmer (natural farming practitioner, female, 30 years old, 0.5 acres) said *"Previously if you invest Rs 15,000/-, we will incur Rs 10,000/- as production expenses. So, we would be left with Rs 5,000/-. Now that's not the case. Purchase of groundnut flour, jaggery and cow dung are our manure, which are of low cost. Also, there is guidance given to us by the iCRP* [a community resource person employed by RySS] *on how to prepare and use them."*

Increases in the labor costs/wage rates have also deterred the farmers from adopting natural farming. A farmer (conventional farmer, male, 34 years old, 0.5 acre) said *"these days the availability of labor work is more. Since the demand for labor has increased, farmers are only cultivating rice needed for the household requirements. If the attitude is so, it won't be profitable. Indeed, the production costs will increase."*

Sub theme 2b: Marketing support

Marketing support was identified as a key factor that would enable conventional farmers to shift to natural farming. A farmer (conventional farmer, male, 27 years old, 0.5 acre) indicated that *"When the government provides marketing facility for natural farming products, everyone will know about it. For every four villages or so, if a marketing facility can be provided that will help uptake of natural farming."* At the same time, those currently practicing natural farming mentioned that most plots under natural farming cultivation were for household consumption or for their 'near and dear.'

Sub theme 2c: Support for inputs

Availability of inputs was identified as a major bottleneck for implementing natural farming. A farmer (conventional farmer, female, 48 years old, 1 acre) remarked *"previously we used to have a lot of animals. A minimum of 4 animals per household. With them we used to apply 15*

truckloads of manure to a half-acre plot. But now, who has animals?" In contrast, a natural farming practitioner (female, 45 years old, 1.5 acres) informed that *"That's why NPM shops were set up, we buy inputs from them for forty rupees and thirty rupees per liter. Not all men are at home. Someone may go out for duty, ladies may work hard and have no time after taking care of the children, so motivation is mostly done through NPM shops."*

A similar response was echoed during interactions with farmers from other villages. Farmers said the input barrier could be overcome by setting up NPM shops. NPM shops, set up at the village level, offer concoctions and botanical extracts prepared using cow dung, urine and other naturally available products [30]. A farmer (conventional farmer, male, 60 years old, 50 cents) said *"If we are to convert completely to natural farming, then we should set up NPM shops. For any farmer to observe and prepare concoctions based on the pest, it will result in the loss of valuable time. So, the farmer is incentivized to immediately visit a pesticide shop, purchase the pesticide and spray it immediately. So, if the NPM shop with ready availability of inputs is ensured, then we will buy them."*

Theme 3: Natural farming as a labor and knowledge intensive process

Sub theme 3a: Labor-intensive farming

Farmers from both groups felt that natural farming was a labor-intensive process. A conventional farmer (female, 40 years old, 2 acres) said *"It takes a lot of effort to undertake natural farming. Neither does the government supply the input by setting up shops. If that happens the farmer will be incentivized to buy the natural inputs instead of chemical inputs. Now farmers and people are ready to take whatever is simple. No one is ready to work hard."* Similarly, another conventional farmer (male, 75 years old, 2 acres) remarked "*Now we are there, and we can't go anywhere. In that case, if you wish to do something great it's not possible, we have been rolling like that for 10, 20, 30 years. Now we have become old and not able to carry weights We are not able to carry the weights."*

Sub theme 3b: Knowledge-intensive farming

Farmers believed natural farming is a knowledge intensive process and hence requires a variety of dissemination mechanisms for promoting on a wider scale. In the words of a farmer (natural farming practitioner, female, 33 years old, 1.0 acre), *"it's because of them* [iCRP] *we started implementing natural farming. Otherwise, we do not know, and most farmers have forgotten this age-old practice. Because they are in the village, they are educating the farmers and training us in various practices. In our village, where it has been difficult to prepare concoctions, they set up NPM shops, so it has become easy for us to purchase natural inputs."* Similarly, another farmer (natural farming practitioner, female, 33 years old, 1.0 acre) expressed *"If you make a good video of something like this and show it to everyone on TV in focus, it will change them a little. They don't need to hold meetings like this when they go to another town to take an interview for an hour, half an hour or two hours and tell them what to do. If you sit them down and show them a calm movie, it will change. Because I don't even know what information is. Even though I'm educated! This is something that is very deep."*

While the farmers think natural farming is knowledge intensive, they wanted to adopt natural farming in order to revive traditional practices. A farmer (natural farming practitioner, female, 60 years old, 1.5 acres) said *"My ancestors used to preserve seeds and used charcoal dust to save the seeds from getting spoilt. Now the women of the village are learning those practices."*

Sub theme 3c: Peer effect

Peer support casts a significant influence on the methods practiced at the farm level. The peer influence is not necessarily in the direction of enabling environment for adopting natural farming, rather the prevailing practices of fellow farmers may often disincentivize the farmers who are inclined to adopt natural farming. For example, a farmer (conventional farmer, male, 49 years old, 2 acres) said *"90% of the reason for resorting to spraying is because I am using it, and you are not using it. Because of that, whatever efforts I have put into practicing natural farming is*

lost, in the fear that I might incur losses." Similarly, a farmer from one of the FGD informed that there were instances where water from a conventional farm flowed onto a nearby natural farm. Hence, the practices followed by neighboring fellow farmers are proving to be one of the influential factors for adopting natural farming.

Quantitative phase

Questionnaires were administered to 1126 households across 4 AP districts. 1103 respondents practiced conventional farming while only 23 respondent practiced natural farming to any degree. Natural farming practitioners were relatively more educated (65% graduate or professional degree, compared to 43% in conventional farmers) while 65% belong to the Other Backward Caste (Table 2). Natural farming practitioners had been engaged in farming for longer than conventional farmers and had slightly larger farms.

Table 2: Characteristics of households who participated in the quantitative survey on barriers and facilitators to adopting natural farming in Andhra Pradesh, India (n=1126).

Variable	**Conventional farmers (n=1103)**	**Natural farming practitioners (n=23)**
Districts		
Kurnool	33% (364)	13% (3)
Visakhapatnam	2.4% (27)	0% (0)
Nandyal	17% (189)	8.7% (2)
Anakapalli	47% (523)	78% (18)
Respondent's education		
Illiterate	5.8% (64)	0% (0)
No formal schooling	7.3% (80)	4.3% (1)
Primary school	7.8% (86)	8.7% (2)
High School	21% (237)	4.3% (1)

Secondary school	39% (429)	35% (8)
Graduate	14% (152)	17% (4)
Professional	5.0% (55)	30% (7)
Respondent's occupational status		
Farming	55% (606)	39% (9)
Agricultural labour	4.1% (45)	4.3% (1)
Livestock rearing/grazing	1.2% (13)	0% (0)
Non-agricultural/casual labour	19% (206)	30% (7)
Salaried (scale based/higher level)	3.9% (43)	8.7% (2)
Salaried (low salary)	12% (136)	13% (3)
Artisan/craftsman/households industry/technical services	0.2% (2)	4.3% (1)
Contractor/Broker/Local services	1.0% (11)	0% (0)
Petty business/trade/vendor/hawker	2.7% (30)	0% (0)
Other	0.7% (8)	0% (0)
Respondent's caste (Social group)		
Scheduled Caste	11% (124)	4.3% (1)
Schedule Tribe	1.0% (11)	0% (0)
Other Backward Caste	64% (703)	65% (15)
General/other	22% (238)	30% (7)
Muslim	2.4% (27)	0% (0)
Aware of natural farming (% yes)	31% (368)	96% (22)
Farming practices	98% (1103)	2.0% (23)
Years in farming	13.3 (1103)	22.5 (23)
Total farm size (hectares)	1.19 (1103)	1.29 (23)
Land under cultivation (hectares)		

(Top 5 crops based on cultivated area)		
Paddy	27% (293)	48% (11)
Cotton	20% (225)	9% (2)
Vegetables	12% (139)	0% (0)
Fruits	6% (72)	0% (0)
Black gram	2% (29)	4% (1)
Values are mean (SD) or % (n).		

Practices adopted by natural farming practitioners

Among the 23 farmers who reported adopting natural farming on some of their land, the most frequently adopted practice was the use of Jeevamrutham (a bio inoculum made with cow dung, cow urine, jaggery, pulse flour, water and soil) and minimum tillage (**Figure 2**). Other common practices included minimum tillage, seed treatment, the use of indigenous seeds, pre-monsoonal dry sowing, and mulching. Notably, only five farmers reported completely abstaining from chemical pesticides.

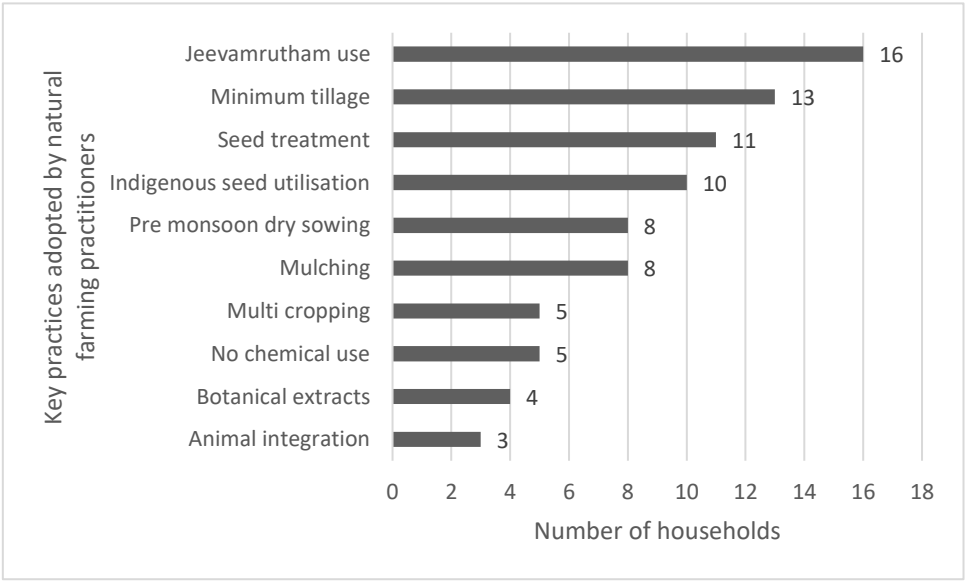

Figure 2: Practices adopted by 23 natural farming practitioners among the surveyed participant households across four districts in Andhra Pradesh, India (2023).

Motivations for adopting natural farming

The most cited motivation for adopting natural farming was improved household health, followed by a willingness to experiment with natural farming practices and observed improvements in soil health (Table 3). Factors such as women's self-help group training, family support, and peer influence were mentioned less frequently as motivating factors.

Table 3: Reasons for adopting natural farming among natural farming practitioners across four districts in Andhra Pradesh, India (2023, n=23 households).

Influencer	**Reported level of influence**		
	Significant	**Moderate/Low**	**Can't say**
Improved household health	100% (23)	0% (0)	0% (0)
As an experiment	78% (18)	18% (4)	4% (1)
Improvements in soil health	70% (16)	26% (6)	4% (1)
Reduced health expenditure	57% (13)	43% (10)	0% (0)
iCRP availability	57% (13)	30% (7)	13% (3)
Reduced input cost	57% (13)	30% (7)	13% (3)
Crop resilience	39% (9)	47% (11)	13% (3)
Low irrigation requirement	30% (7)	56% (13)	13% (3)
Higher/Premium price for the naturally farmed produce	26% (6)	43% (10)	30% (7)
SHG trainings	13% (3)	39% (9)	48% (11)
Family support	13% (3)	39% (9)	48% (11)
Fellow farmers' influence	9% (2)	39% (9)	52% (12)

Values are % (N).

Abbreviations: iCRP - internal community resource person; SHG, (women's) self-help groups.

Barriers limiting the adoption of natural farming

Among conventional farmers who did not report adopting natural farming, perceived yield penalty was the primary reason, followed by the lack of knowledge and the complexity of natural farming practices (**Table 4**). Having access to only a small plot of land and high labor costs were least cited as significant barriers.

Table 4: Barriers that limited the adoption of natural farming reported by conventional farmers (n=1103) across four districts in Andhra Pradesh, India (2023).

Barriers	**Reported level of barrier**		
	Significant	**Moderate/Low**	**Can't say**
Decreased yield	48% (532)	13% (147)	39% (424)
No knowledge of Natural farming	39% (435)	20% (222)	41% (446)
Not easy to practice NF	39% (430)	12% (131)	49% (542)
Increased family labour	35% (383)	28% (307)	37% (413)
Lack of premium price	30% (326)	28% (312)	42% (465)
Lack of government procurement	24% (266)	31% (336)	45% (501)
No ready availability of inputs	17% (183)	26% (285)	57% (635)
Time consuming preparatory process	16% (181)	24% (260)	60% (662)
None of my fellow farmers practice NF	33% (360)	23% (254)	44% (489)
High labour costs	11% (120)	42% (465)	47% (518)
Small land extent (≤0.5 acres)	9% (99)	27% (304)	64% (700)

Perceived facilitators of natural farming uptake

Among both conventional and natural farming practitioners, key enablers for transitioning to natural farming include the support of an iCRP, access to certified seeds, input and material support (drums, weeders, cows, etc.) (Table 5). However, the needs diverge slightly between the two groups. Conventional farmers benefit significantly from marketing support and

354 the establishment of NPM shops, ensuring ready availability of inputs, which might facilitate their
355 shift. In contrast, natural farming practitioners emphasize the need for Pico presentations
356 (presentations done using a mobile or handheld projector) and on-field demonstrations to
357 deepen their understanding and enhance their practices.

Table 5: Facilitators of natural farming adoption identified by participant households (n=1126 participants) across four districts in Andhra Pradesh, India (2023).

Variable	Conventional farmers (N=1103)	Natural farming practitioners (N=23)
Presence of an iCRP		
No	7.3% (81)	0.0% (0)
Yes	93% (1,022)	100% (23)
Pico presentations		
No	50% (552)	13% (3)
Yes	50% (551)	87% (20)
Infra (material) support		
No	29% (324)	13% (3)
Yes	71% (779)	87% (20)
Input support		
No	39% (434)	39% (9)
Yes	61% (669)	61% (14)
Certified seed availability		
No	19% (208)	17% (4)
Yes	81% (895)	83% (19)
Marketing support		
No	35% (383)	57% (13)
Yes	65% (720)	43% (10)
NPM shop setup		
No	42% (465)	57% (13)
Yes	58% (638)	43% (10)

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DISCUSSION

A range of factors influence farmers' adoption of sustainable farming practices in the context of a government-funded and implemented transition program in south India. Farmers' health emerged as a major motivating factor for adopting natural farming, in both qualitative FGDs and a quantitative survey (23 natural farming practitioners responded to the survey). However, farmers perceived natural farming to be labor- and knowledge-intensive and identified support from iCRPs and increased availability of inputs at NPM shops as solutions. A perceived yield penalty was a significant barrier to conventional farmers adopting natural farming but did not emerge in FGDs as a barrier to continuing to practice natural farming amongst farmers already engaging in these practices. Given the low intervention adoption rate observed after the first year of training in the context of this cluster-randomized controlled trial, it is clear that these barriers need to be addressed if the government is to achieve its ambition of transitioning all farmers in the state to natural farming.

Health emerged as a major motivating factor for adopting natural farming and was recognized by both current natural farming practitioners and conventional farmers. These perceived health benefits are consistent with the findings of a recent cross-sectional survey conducted by GIST Advisory of 280 respondents (both natural farming practitioners and conventional farmers) in 2023, which found a strong correlation between transitioning to natural farming and lower on-farm health risks (pesticide and occupational exposures), health-related productivity losses, and health expenditures [31,34].

A perceived yield penalty remains the most cited reason by conventional farmers for not adopting natural farming. However, the Centre for Social Sciences report on 'Assessing the Impact of APCNF'—which utilized crop cutting experiments—found no statistically significant difference in yields between natural and conventional farming for eight out of eleven surveyed crops [35]. In contrast, a meta-analysis by Crowder & Reganold on the financial competitiveness of organic agriculture concluded that organic farming generally results in lower yields [36]. In the Indian

context, Kumar's study reported a 37% yield disparity (24 tons for conventional and 15 tons for organic) in tomato cultivation in Northern India [37], while Reddy observed a 12-18% decline in yields under organic farming [20,21]. On the other hand, plot experiments in Andhra Pradesh have shown significantly higher yields in naturally farmed plots compared to conventional ones [19]. Similarly, a study in Karnataka found that 82% of farmers practicing natural farming experienced yield gains, with a 91% increase in crop income [38]. To explain this heterogeneity in findings, more 'real world' (i.e. not controlled plots) research is needed to understand the impact of contextual factors on yield as farmers transition to natural farming.

Farmer households consistently acknowledged that natural farming is a knowledge-intensive process. To facilitate the shift from conventional agriculture to natural farming, they emphasized the crucial role of the iCRP as a key change agent. Both qualitative and quantitative findings underscore the iCRPs centrality in enhancing farmer awareness and adoption of natural farming practices. While the APCNF intervention is routed through Self-Help Groups, it is the iCRP who effectively bridges the knowledge gap on the ground. Evidence from studies evaluating the impact of state-led organic farming trainings show that farmers who interact with resource persons more than once a week are significantly more likely to reduce synthetic pesticide use—further reinforcing the critical role of iCRPs in advancing natural farming [22].

At the same time, farmers expressed the need for additional dissemination strategies such as Pico projectors (a handheld image projector device) and local demonstration sites to bolster awareness and adoption. Beyond information access, the labor-intensive nature of natural farming also emerged as a core concern. Therefore, the supportive ecosystem in the form of material input support can play a vital role in addressing labor-related barriers. The establishment of NPM shops for timely availability of inputs—like concoctions and drums—can significantly ease the preparation workload and smoothen adoption. Schemes like Gokulam (Cow shed establishment) [39], though not directly linked to natural farming, indirectly contribute by

promoting cattle infrastructure that improves access to raw materials essential for these practices.

Building an enabling ecosystem also requires innovative policy support mechanisms. For example, marketing and training could be delivered through farmer cooperatives such as farmer producer organisations. A recent study in Uttar Pradesh found that membership in a farmer producer organisation is associated with higher crop diversity and household income [40]. Institutional support of this nature not only facilitates adoption but also lays the foundation for a long-term shift towards sustainable, community-driven farming practices.

In summary, the need for iCRP support, ready access to inputs and need for certified seed availability is expressed by all the farmer groups. Conventional farmers especially mentioned the need for a supply of ready-made inputs and marketing support to encourage them to adopt natural farming practices. In a study conducted by Balla and Kishor [41] on understanding the constraints and reasons to adopt natural farming among rice-growing farmers in Andhra Pradesh, they also observed that strengthening market linkages, supportive policies of the government, and human health were important reasons for adopting natural farming. However, the current study found that natural farmers expressed the need for infrastructure (material) support and to receive more information on natural farming through various dissemination mechanisms.

The study benefited from the lead investigator’s deep familiarity with the intervention context and proficiency in the respondents' native language, ensuring meaningful engagement. While our study findings underscore the importance of various factors in enabling farmers to transition to natural farming, it has certain limitations in fully capturing the true reasons behind farmers' choices. Although the study benefited from conducting FGDs in APCNF Phase 1 villages, which had an enabling environment due to earlier interventions like non-pesticide management, this was not the case in the BLOOM villages where quantitative surveys were conducted. Analyzing FGDs in the native language allowed for an authentic representation of farmers'

perspectives on natural farming. Furthermore, the mixed-method study design enhanced the exploration of barriers and facilitators, capturing insights from farmers in the early stages of transition—contrasting with FGDs that focus on later stages, making this the first study to undertake such a nuanced investigation.

The study's limitations include - first and foremost, that the findings are context-specific and may not be generalizable to other contexts, even within India. The small number of natural farming practitioners during the quantitative phase limited our ability to explore differences in motivations across different groups such as by crop and farm size. Finally, health as main motivator may have emerged because of bias from the affiliated organization of the interviewer and the broader context of the BLOOM study which is focused on health effects of APCNF.

CONCLUSIONS

In conclusion, this study underscores the critical role of iCRPs and NPM shops in enabling farmers to adopt natural farming. Quantifying and communicating the health co-benefits and creating markets for naturally farmed products may further motivate farmers towards adoption. Also, the findings underscore that farmer households cannot be viewed as a homogenous group; instead, tailored strategies should address the specific needs of various farmer categories.

These insights are particularly significant where natural farming interventions are recognized as vital strategies to build resilience to climate change on a national scale. India's diverse agricultural landscape necessitates a comprehensive approach, incorporating various elements to encourage farmers to transition to an agricultural system that aligns harmoniously with nature. By adopting such a holistic strategy, we can support the sustainable development of agriculture and enhance the resilience of our farming communities.

Declarations:

Ethics approval:

The qualitative phase of this study was approved by the Institutional Review Board of the Public Health Foundation of India (Ref No: TRC – IEC 502/ 23) and the Human Ethical Review Committee of the University of Edinburgh (Ref No: HERC_703_21). The quantitative phase of this study was approved by the Human Ethical Review Committee of the University of Edinburgh (Ref No: HERC_703_21) and Ashoka University (HREC No. AUHREC/10062023/meeting2/002-6).

Consent for publication:

Written informed consent was obtained from all participants for the publication of the data, with assurances that their identities would remain confidential and anonymized.

Data sharing statement:

The quantitative data will be made available upon publication on Edinburgh DataStore. Due to potential identifiability, qualitative data is not publicly available.

Competing interests:

The authors declare that they have no competing interests.

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Authors contributions

YB, NSV and LMJ conceived the research question and study design. YB conducted the FGDs and developed the quantitative questionnaire with the support of LMJ. YB conducted the statistical

analysis with the support of SR and LMJ. YB drafted the initial manuscript with support from LMJ. All the authors provided substantive feedback on the manuscript and approved the final version.

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602

Additional File 1: FGD Participant details

Village	Block	District	State

603

1. Farmer name	
2. Father's name	
3. Age (in years)	
4. Education level (years of education)	
5. Operational landholding (in acres)	
6. Since when are you practicing agriculture	
7. Season, since the natural farming is practiced	
8. Any shift back to conventional farming methods	
9. Major crops grown in the last cropping season (2022-23)	
10. Phone number	

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Additional File 2: Focus Group Discussion question guide

Date of FGD: Discussion start time: Venue:

Name of the moderator: Name of the note taker:

Instructions – Before starting the discussion, please seek written informed consent from all farmers for participating in the discussion and audio recording of the discussion.

Before the start of discussion, please introduce yourself and introduce participants to each other. Please brief the participants about the purpose of the study and the purpose of the discussion. The participants will also be informed about the significance of their contribution to the discussion. Kindly reiterate that participation is purely voluntary and the information that they provide will be kept confidential with access to only the study investigators. Kindly inform you that the participants are free to withdraw from the study, at any time to the point of data analysis. Please also inform that their names will not be revealed while reporting the results. Please let them know that the discussion may last up to one hour. Please ask the participants if they have any queries and clarify them before proceeding with the interview.

Before starting the audio recording, state "Audio recording started".

PLEASE ENSURE ALL PARTICIPANTS HAVE SIGNED THE CONSENT FORM BEFORE COMMENCING THE DISCUSSION

1. Current farming practices:
    a. What are the common cropping patterns practiced in your village?
    b. What are the common agricultural practices being employed by the farmers in the village?
    c. What are the major changes observed in the last 5 years?
2. Alternate farming practices:
    a. Have you experimented with any alterative farming methods like organic farming or zero budget natural farming?
        i. If yes, how was that experience? Are you still doing this?

631 ii. If yes or no, why?

632 b. For how long have you practiced organic farming?

633 c. What portion of the land is under organic farming?

634 d. What are the key influences that motivate you to shift/abandon natural farming?

635 e. What are the top challenges you are facing in implementing NF on your farm?

636 f. According to your experience, what is the future of farming in your region?

637 3. Influencing factors:

638 a. Change in Income:

639 i. How has the farm incomes have changed in the last 5 years?

640 ii. How have the input costs changed since you started practicing NF?

641 iii. What was the per acre net profit from the crop you grew?

642 iv. How have the farm income changed in the last 5 years?

643 b. Changes in soil quality:

644 i. Have you experienced any changes in soil quality at your farm in the last 10 years?

645 ii. If yes, what are those changes?

646 iii. How are they affecting your farming practices in terms of changes in farm input?

647 c. Availability of input resources:

648 i. Do you have the knowledge of preparing Jeevamrutham (Ghana and Dhrava)?

649 ii. Is NPM shop available in the village?

650 iii. Do you think you can easily procure your resources?

651 d. Availability of trained manpower:

652 i. How effective is the iCRP helping you to shift to NF?

653 ii. Are there any additional manpower resources that helped you to shift to natural

654 farming

655 e. Water requirement:

656 i. Have you seen any changes in groundwater levels in the last 10 years?

ii. If yes, what are those changes both in terms of water quantity (fall or rise in the groundwater table) and/or quality (changes in quality of groundwater quality)?

iii. How have these changes affected your farming practices in terms of changes in cropping patterns and farm input costs?

4. Family health:
    a. Do you think farm practices have an impact on your family health?
    b. If yes, what are those changes?
5. Government policy:
    a. Are you aware of government policies related to agriculture in your region?
    b. If yes, what are those policies?

Summarize key points which emerged from the discussion and ask if they agree with the discussion summary. If any member has a different viewpoint, please note it down. Also ask if they'd like to add anything that has been missed in the discussion.

Thank the participants for participating in the discussion.

Discussion end time: _____

673 **Additional File 3: Barriers and facilitators to promote Natural Farming**

INTERVIEW DETAILS			
No.	**QUESTION**	**OPTIONS**	**RESPONSE**
1.	Today's date	DD/MM/YYYY	
2.	Interviewer ID	Text	
3.	Household ID	XXXX	[4 numeric digits]

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No.	**QUESTION**	**OPTIONS**	**RESPONSE**
1.	Do you currently work in agriculture?	Yes = 1 No = 0 [end survey]	
2.	Are you an agricultural laborer?	Yes, only agricultural laborer = 1 [end survey] Yes, but also cultivate land = 2 No = 0	
~~3.~~	How much agricultural land does your household own?	_ Acres _ hectares _ guntas	
4.	Are you aware of Natural Farming	1, Yes 0, No	
5.	Have you adopted natural farming?	1, Yes [skip to Q6] 0, No [skip to Q25]	
6.	What is the total extent of land on which you practice under natural farming?	_ Acres _ hectares _ guntas	

7.	How long have you been practicing NF?	Kharif '23 Rabi '22 PMDS Others (please specify)				
8.	Is the NF plot purely NF	1, Completely NF 0, Partially NF				
9.	What are the key NF practices being adopted?	1, PMDS 2, Minimum tillage 3, Seed treatment 4, Use of indigenous seed 5, Applying Jeevamrutham 6, Mulching 7, Diverse crops, trees, incorporated on the farm 8, Integrated animals into the farm. 9, Pest management through botanical extracts 10, No synthetic fertilizers, herbicides, pesticides 11, Other practices				Tick all that apply
10.	To what extent have the following factors influenced your decision to shift to natural farming?	Significant influence	Moderate influence	No influence at all	Can't say	
11.	Improved health					

12.	Reduced health expenditure					
13.	Improvements in soil health					
14.	Low irrigation requirement					
15.	Resilience of crops to environmental shocks					
16.	Reduced input cost					
17.	Higher premium for the NF produce					
18.	Support of the family					
19.	Availability of iCRP					
20.	Most farmers in my village are practising NF					
21.	Trainings in SHGs					
22.	As an experiment					
23.	Have any other factors influenced your decision to shift to natural farming?	1, Yes 0, No				
24.	If yes, what other factors?	Text				
25.	To what extent have the following barriers stopped you from adopting NF?	Significant influence	Moderate influence	No influence at all	Can't say	Read out each option and capture

						their responses
26.	High labour costs					
27.	Increased family labour					
28.	Decreased yield					
29.	Lack of premium price					
30.	Lack of government procurement					
31.	No knowledge of Natural farming					
32.	No ready availability of inputs					
33.	Time consuming preparatory process					
34.	None of my fellow farmers practice NF					
35.	Small land extent (≤0.5 acres)					
36.	Not easy to practice NF					
37.	Have any other barriers influenced your decision to shift to natural farming?	1, Yes 0, No				
38.	If yes, what other barriers?	Text				

39.	What would have facilitated you to take up NF?	1, Presence of an iCRP 2, More motivation/ demonstration sites 3, Support for inputs (drums, weeders, cows, etc) 4, Ready availability of concoctions through an NPM shop 5, Government certified seed supply 6, Marketing support 7, NPM shops set-up 8, Others (please specify)	Tick all that apply

675


Visakhapatnam
Anakapalli
Nandyal
Kurnool
Andhra Pradesh
0 500 1,000 km

Figure