NATURAL FARMING THROUGH A WIDE-ANGLE LENS

True Cost Accounting Study of Community Managed Natural Farming in Andhra Pradesh, India

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GIST IMPACT | GLOBAL ALLIANCE FOR THE FUTURE OF FOOD

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Photo caption: Pala and Bhavani Suryanarayana, APCNF farmers in Annavarapupadu, East Godavari.
Photo credit: APCNF 2023

EXECUTIVE SUMMARY

Andhra Pradesh Community-Managed Natural Farming (APCNF) is a state-wide agro-ecological transformation of the farming practices of its 6 million farmers over 6 million hectares and 50 million consumers. It is the largest transition to agroecology in the world, with 630,000 farmers already addressing multiple development challenges: rural livelihoods, access to nutritious food, biodiversity loss, climate change, water scarcity, and pollution. This research into the APCNF program, led by GIST Impact and supported by the Global Alliance for the Future of Food, started in 2020. The study is the first of its kind to assess the true costs and benefits of natural farming against other counterfactual farming methods by measuring all major economic, social, and health impacts.

The research used The Economics of Ecosystems and Biodiversity for Agriculture and Food Systems (TEEBAgriFood) framework: a holistic approach to comprehensively examine food systems and systematically identify links between agricultural practices and human well-being so that appropriate policy responses can be developed and adapted globally.

This study compared the impacts of APCNF with three other farming systems in Andhra Pradesh: chemical farming in the Godavari delta region, rainfed farming in the semi-arid region, and low-input tribal farming in the mountain region.

The results show strong evidence that APCNF offers a better alternative to the existing farming systems.

Adopting APCNF led to greater crop diversity, similar or higher yields, higher incomes for farmers, lower input costs, improved local economies, improved social networks, improved health, and reduced health costs. Overall, APCNF gave highly positive returns on public investment, suggesting APCNF to be the food production system with better economic, environmental, and social outcomes.

Economic Impacts

- Crop diversity was higher on APCNF farms: an average 4 crops compared to 2.1 on counterfactual farms.
- Yields of prime crops—paddy rice, maize, millet, finger millet, and red gram—increased by an average 11% in APCNF villages.
- APCNF farmers saw an average 49% net increase in income. This was largely the result of a 44% (average) reduction in input costs, primarily fertilizers and pesticides.
- Labour intensity on APCNF farms was 21% higher than comparison farms.

Social Impacts

- APCNF led to increased social capital in villages. Social capital includes: information sharing, mutuality, collective action, trust and support, community cohesion, and risk reduction.
- Increasing the social capital created a "virtuous cycle" of increased economic gains, which in turn led to greater trust, cohesion, and reciprocity.
- Women significantly influenced social capital; particularly knowledge sharing, community cohesion, and trust and support.
- The results show that smaller farms had higher social capital scores than larger farms, suggesting that smallholder farmers are important to developing social capital within communities.
- APCNF farms had greater social capital than non-APCNF farms, likely due to the greater networking and mutual support.

Health Impacts

- The research showed strong correlation between lower on-farm health risks and transitions to APCNF farming. For example, farmers on APCNF farms lost one-third fewer working days to illness, compared with farms using counterfactual farming methods.
- The use of chemical pesticides and fertilizers correlated with higher incidence of short-term exposure and symptoms. This in turn correlated with higher health costs and productivity losses for farmers. Such health impacts are not accounted for in conventional market-based crop-pricing models.
- The health-cost analysis, based on health expenses incurred and wages lost due to illness, showed that villages with chemically intensive farming had the highest health costs: 26% higher than those for APCNF farmers in this region.
- Household Dietary Diversity was greater in APCNF households than in other conventional farming households, indicating access to a greater variety of crops.

So what?

- Importantly, this study shows that natural farming and agroecological transitions can comfortably feed communities with better yields and crop diversity than conventional farming methods, with important insights for policy makers in India and globally.
- The scale of APCNF demonstrates that agro-ecological practices can be scaled to meet the demand for food while addressing multiple environmental and social goals.
- While public investment costs for APCNF were higher than on counterfactual farms, the higher costs for farmers, communities, and the environment associated with counterfactual farming (loss of work hours, poorer health, and poorer soils) meant that APCNF actually resulted in a better holistic return on investment.
- Using True Cost Accounting (TCA) and the TEEBAgriFood framework highlighted the economic, social and human health benefits associated with APCNF and the increased costs associated with counter-factual farming. These would not be accounted for under traditional "yield-and-profit-only" metrics, but clearly show better returns on public investment after accounting for public benefits and costs.
- Using TCA can provide a holistic analysis to inform policy decision-making that aims to enhance economic development, reduce poverty, and improve health and environmental outcomes.
- Given ongoing climate impacts, there is an urgent need to scale inclusive climate-resilient models of agriculture. This research offers a clear assessment of environmentally friendly agricultural development that also supports social and economic goals.

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List of acronyms

Agenda 2030: the 2030 agenda for sustainable development (by United Nations)

APCNF: Andhra Pradesh Community Natural Farming

CBD: Convention on Biological Diversity

CNF: community natural farming

FCT: Food Consumption Table

GA: Global Alliance for the Future of Food

GDP: gross domestic product

GHG: greenhouse gases

NGO: non-governmental organization

PC: principal component

PCA: principal component analysis

RySS: Rythu Sadhikara Samstha

SHG: self-help group

TEEB: The Economics of Ecosystems and Biodiversity

TEEBAgriFood: The Economics of Ecosystems and Biodiversity for Agriculture and Food Systems

UNCDD: United Nations Convention to Combat Desertification

UNEP: United Nations Environmental Programme

UNFCCC: United Nations Framework Convention on Climate Change

ZBNF: Zero Budget Natural Farming

Foreword

The United Nations has endorsed a series of important global agreements: the Sustainable Development Goals (SDGs) of the 2030 Agenda; the Paris Agreement; and the Rio Conventions, which address, respectively, climate (UNFCCC), land restoration (UNCCD), and biodiversity (CBD). At very high levels, these agreements deal with a broad range of topics of the highest importance for the future of humanity. Without a doubt, two of the most important and urgent tasks are: 1) providing healthy food for all, and 2) improving livelihoods in rural communities while respecting planetary boundaries.

In today's increasingly industrialized and concentrated agri-food systems, more than 825 million people are hungry and over 2 billion people are malnourished. At the same time, unsustainable food production contributes to accelerated biodiversity loss, climate change, and other environmental impacts. The global competition for "cheap food" is also undermining more biologically diverse and climate-resilient food production and distribution systems that are built around smallholder production and local markets. Transformative agricultural practices, on the other hand, have the potential to future-proof eco-agri-food systems. Food systems transformation is imperative to providing healthy food for 10 billion people on a healthy planet.

For the first time, in this report, we are comprehensively analyzing the Andhra Pradesh Community Managed Natural Farming (APCNF) program, which many people consider a beacon of hope for showcasing how food systems transformation can work for rural communities. APCNF's innovations serve as a laboratory for change and showcase the opportunities for rural communities. However, we cannot analyze, measure, and value the success of APCNF with the existing toolbox of traditional economics.

I am very happy to see that this study is both a comprehensive analysis of a new model of agriculture and solid proof of the TEEBAgriFood Evaluation Framework for valuing positive and negative externalities of a concrete food system. This report is the largest agricultural study of this type, per number of farmers, and the most expansive, considering the analysis of all four capitals (natural, financial, social, and human) that are relevant to fully capture the positive and negative externalities of today's food systems.

The holistic approach of TEEBAgriFood enables us to see the excellent results of APCNF in three unique ways: 1) in the improvement of the variety of food produced, 2) in the improvement of the farmers' health, and 3) in the ways existing social capital is used to diffuse natural farming techniques and knowledge. Importantly, net profits of farmers and yields were preserved, and the semi-arid area was improved.

When considering natural farming over chemically intensive farming, loss of profit is usually a concern. However, here we show how that pitfall can be avoided. Only with an approach like TEEBAgriFood can a comprehensive analysis of natural farming be undertaken and the impacts of natural farming on natural, social, financial, and human capital be unveiled. Traditional economics would hide many of these advantages!

In sum, community natural farming empowers farmers financially and socially; it provides innovative solutions for dealing with scarce and degraded natural resources; and it highlights the importance of social capital. TEEBAgriFood provides the toolbox to prove it!

Alexander Müller

Abstract

Global agriculture and food systems are not on track to achieve the targets set by Agenda 2030 to achieve zero hunger and eradicate malnutrition by 2030. There is an urgent need to develop strategies that can provide enough nutritious food for all in a manner that enhances livelihoods and does not damage the environment and human health.

The Economics of Ecosystems and Biodiversity for Agriculture and Food Systems (TEEBAgriFood) program took a holistic approach to examining agriculture so that appropriate policy responses can be developed to fix our broken food systems. TEEBAgriFood systematically identifies material links that food systems have with several dimensions of human well-being.

This study examines the economic, social, and health impacts of Andhra Pradesh Community Managed Natural Farming (APCNF; hereafter CNF) compared to three different farming systems prevalent in the state of Andhra Pradesh, India: low-input farming in the montane-forested tribal region, low-input rainfed farming in the semi-arid southwestern region, and high-input farming in the Krishna-Godavari delta region.

We have gathered strong evidence that CNF offers a better alternative to the existing and still dominant farming systems across all three agroecological regions. The adoption of CNF has led to improvements in crop diversity, comparable or higher yields, higher incomes, lower input costs, improved social capital, and improved health, and correlates with lower health costs in all three regions that were analyzed. Overall, CNF gives positive returns on public investment. Social capital compensated for the lack of education and experience, enabling the CNF farmers to reap productivity gains. The average economic loss was highest in villages where chemically intensive farming was practised, proving CNF to be the food production system with better returns both in terms of farm economics and human well-being.

Executive summary

Global agriculture and food systems are not on track to achieve the targets set by Agenda 2030 to achieve zero hunger and eradicate malnutrition by 2030 (FAO, 2022; Sandhu, 2021). Over 825 million hungry people do not have access to safe, nutritious, and sufficient food, and malnutrition is growing (TEEB, 2018; FAO, 2022). There is an urgent need to develop agriculture and food systems that can provide enough nutritious food for all without damaging the environment and human health (Sandhu, 2021). There is also a need to understand the various impacts of our current food systems so that more sustainable food systems can be developed to meet the ecological and food security of the growing population. One such tool, widely known as The Economics of Ecosystems and Biodiversity for Agriculture and Food Systems (TEEBAgriFood) Framework has been developed by world-leading experts to examine agriculture and food systems more holistically (TEEB, 2018). This Framework has been developed by the United Nations Environment Programme and supported by the Global Alliance for the Future of Food. It aims to develop appropriate policy responses to fix our broken food systems by systematically identifying material links that food systems have with our well-being.

The TEEBAgriFood Evaluation Framework aims to identify food systems that are inclusive, equitable, environmentally sustainable, able to provide food and nutritional security, and that can support the livelihood of a large number of populations. One such example is Andhra Pradesh Community Managed Natural Farming (APCNF; hereafter CNF) in India, which has grown tremendously over the last few decades. It started as a peasant-led social movement but has grown significantly over the years, with more than 630,000 farmers practising CNF in Andhra Pradesh alone. This study intends to compare the impacts of CNF and conventional farming systems so that sustainable food systems can be further supported by agricultural policy at the state and national levels.

We applied the TEEBAgriFood Evaluation Framework to measure and quantify the economic, social, and health impacts of CNF compared to three different farming systems in three agroecological regions that are prevalent in the state of Andhra Pradesh, India: low-input farming in the montane-forested tribal region, low-input rainfed farming in the semi-arid southwestern region, and high-input farming in the Krishna-Godavari delta region.

We used primary studies that include crop-cutting experiments to evaluate yields in 13 districts and also conducted a large primary household survey during 2020–2022 in 3 districts of Andhra Pradesh, where CNF is actively practised. These sites were chosen to mirror different agroecological conditions. For each district, 2 CNF and 2 counterfactual villages were selected, with a total of 12 villages in 3 agroecological zones. Data was collected from 562 farming households, comprising about 10% of the total farming households across 3 agroecological zones.

Overview

1. The average CNF farm size was 1.81 hectares (ha), whereas the average low-input farm in the montane-forested tribal region was 1.91 ha. Among the low-input rainfed farms in the semi-arid southwestern region, CNF farm size was 0.95 ha compared to 1.63 ha in counterfactual villages. Among the high-input farms in the Krishna-Godavari delta region, the average CNF farm size was 1.23 ha compared to 2.13 ha in counterfactual farms. Smallholder farmers have been early adopters of CNF in all three regions, which indicates that farm size has not been an impediment to the transition to natural farming.
2. The average age of CNF farmers was slightly lower (46 years old) compared to farmers in counterfactual villages (48 years old). There was no significant difference in the age of farmers among the three agroecological zones.

Production & economic impacts

1. The average number of crops grown via CNF was 4.51 compared to 2.16 among those practising low-input farming in the montane-forested tribal region. Among those practising low-input rainfed farming in the semi-arid southwestern region, the number of CNF crops grown was 4.88 compared to 2.40 in counterfactual villages. Among those practising high-input farming in the Krishna-Godavari delta region, the average number of crops grown in CNF farms was 2.92 compared to 1.84 in counterfactual farms. The adoption of CNF has resulted in an average increase in the number of crops grown – from 2.1 to 4 crops – in all three regions, which is highly significant.
2. In all three agroecological regions, the yields of the prime crops, such as paddy, maize, groundnut, finger millet, and red gram, were estimated and compared between CNF farms and counterfactual villages. The average yield increase associated with the adoption of CNF ranges between 7.8 to 25.9%.
3. Labour use was found to be higher among CNF farms practising low-input rainfed farming in the semi-arid southwestern region. In the other two regions, there was no difference in labour use between CNF and counterfactual farms.
4. CNF farmers have lower input costs, falling by 44% compared with the counterfactual farms across three regions. CNF farmers save USD 90 per farm, mainly due to shifts away from synthetic fertilizers and pesticides to locally produced CNF inputs.
5. Gross income per hectare (ha) increases significantly, by USD 684 (+28.3%) overall, with the adoption of CNF across the three regions. It increases significantly among those practising high-input farming in the Krishna-Godavari delta region, by USD 1728 per ha (+42.3%).
6. Net income per ha doubles with the adoption of CNF (by USD 1177or +99.1%) across the three regions. The highest increase per ha is recorded among the high-input farms in the Krishna-Godavari delta region (by USD 2401 or +104.5%), followed by the semi-arid southwestern region (by USD 404 or +88%).
7. Among 77% of CNF farms, farm costs fell, most markedly among the low-input rainfed farms in the semi-arid southwestern region, whereas 87% of CNF farmers reported improvements. Similarly, 67% of CNF farms reported an improvement in farm income.
8. About 70% of CNF farmers showed improved income in the low-input farming in the montane-forested tribal region, 62% in the low-input rainfed farming in the semi-arid southwestern region, and 72% in the high-input farming in the Krishna-Godavari delta region.

Social impacts

1. The aggregate social capital index is high in the villages where CNF is active across all three regions. An empirical analysis of factors favouring the social capital index shows that CNF has succeeded in building social capital among the villagers and that women significantly influenced social capital formation at the farmers' household level.
2. For all six dimensions of social capital – information provision, mutuality, collective action, trust and support, community cohesion, and risk reduction – the scores were higher in the CNF villages.

3. Due to the high existing social capital of Andhra Pradesh, CNF could build on such social capital and reaped productivity gains. In turn, the success of APCNF enhanced local social capital. Of the various dimensions of social capital, trust, reciprocity, and community cohesion have contributed to the significant gains seen in APCNF villages.
4. The results show that the more agricultural land owned, the lower the social capital index, thereby showing that smallholder farmers are active in generating social capital. It was also found that the villages that practised high-input farming in the Krishna-Godavari delta region had higher inequality in landholdings. On the contrary, the more land owned under CNF, the higher the level of social capital.
5. The study showed that CNF has succeeded in building social capital among the villagers, and women significantly influenced social capital formation at the farmer's level.
6. The results of the multiple regression show that in CNF villages, social capital positively contributed to productivity, whereas in counterfactual villages, social capital is negatively related to the value of production.

Health impacts

1. The study showed that CNF farming is associated with reduced on-farm health risks and has lower human health impacts compared to farming in the counterfactual villages in all three regions. This is based on regression analysis of the relationship between the prevalence of symptoms across farmers and their agricultural practices.
2. The study also showed that, on average, CNF farmers lose 121 work days per year due to various illnesses compared to 189 work days in counterfactual farming systems.
3. The health cost analysis based on health expenses incurred and wages lost due to illness showed that average economic loss was highest in villages with high-input farming in the Krishna-Godavari delta region. The losses were 26% higher than those for CNF farmers in this region.
4. The household diet diversity score (HDDS) provides interesting insights into the food habits of farmer households surveyed. The average household diet of farmers surveyed has more macronutrient diversity compared to an average Andhra food plate – indicating that these farmer households have access to a wider range of food crops.
5. CNF households consumed higher amounts of fruits and vegetables compared to counterfactual households, which is not surprising given the presence of multicropping practices and kitchen gardens in CNF households.
6. For CNF villages, when deciding family diet, quality is the biggest driving factor (74%), followed by nutritional content (10%) and price/value for money (9%). In comparison, while non-APCNF households' diets are also driven by quality (55%), prices played a much larger role (28%) when deciding family diets.

Summary of chapters

Chapter 1 introduces and describes the Andhra Pradesh Community Managed Natural Farming (APCNF; CNF hereafter) system, which is compared to the other three in relation to their impacts on natural, social, human, and produced capital by applying the TEEBAgriFood Evaluation Framework in Chapter 2. It is believed that this information will help develop recommendations on feasible transitions toward sustainable, just, and equitable food systems.

Chapter 3 outlines the findings on the economic impact of CNF for practising farmers, particularly on crop yields and net income, and the impacts on rural labour demand and pesticide externalities. We present crop yield and net income data drawn from all 13 districts of Andhra Pradesh, and we focus on farmers from 3 agroecosystems – low-input tribal, low-input semi-arid, and high-input delta region – in 12 villages within 3 of these districts, and analyze the impacts of CNF versus high-input systems (modernized through the Green Revolution), low-input systems, and tribal areas (both largely untouched by modernization). We used a combination of crop-cutting data (n = 1837 farmers) and survey data (n = 480 farmers).

CNF was found to have produced substantial economic benefits for farm households. Yields for various crops (cereals, fibre, vegetables, and fruit) increased in all districts and systems on average by 11%, and net income rose by 49%. Crop diversity on farms increased by 88%, labour use by 20%, and input-use and costs of production fell (pesticide, fertilizer, machinery, seeds). The reduced use of pesticides and fertilizers by 56 to 73% will have also had beneficial outcomes for the health of rural people (reduced pesticide use) and for the reduced nutrient contamination of natural systems (reduced leaching and loss of manufactured fertilizer). Benefits were found in transitions to CNF from all three agroecosystems – chemical, rainfed, and tribal – even though CNF farmers in each system begin adoption from different cultural and agricultural departure points. We conclude that returns on public investment to support transitions toward CNF are positive. These findings add weight to the planned next phases of CNF expansion and wholescale adoption in the state of Andhra Pradesh and elsewhere.

Chapter 4 evaluates the enabling factors and returns to social capital at the farming community level, based on primary research at 557 households across our study's three in-scope farming districts. The results of our Principal Component Analysis show that the aggregate social capital index is high in the villages where CNF is active. An empirical analysis of factors favouring social capital index shows that CNF has succeeded in building social capital among the villagers and that women significantly influenced social capital formation at the farmers' household level. Due to high social capital in Andhra Pradesh as evidenced by well-developed self-help groups for microfinance, CNF could build on such social capital and reap productivity gains. In turn, the success of CNF enhanced the local social capital. Of the various dimensions of social capital, trust, reciprocity, and community cohesion have contributed to the significant gains seen in CNF villages. Two important implications of this study are: 1) that policymakers should consider the many positive impacts of natural farming on the communities, and 2) that it is important to invest in building social capital, which can compensate for lack of education and experience, enabling farmers to adopt natural farming and reap productivity gains.

Chapter 5 focuses on applying the TEEBAgriFood Evaluation Framework for comparing on-farm human health and food-plate diversity impacts of CNF and its alternative practices (i.e., chemical-intensive farming, tribal organic farming, and rainfed farming) adopted by farmers. Key objectives of this chapter are: 1) to analyze the farmers' health impacts from handling and applying agrochemicals; and 2) to analyze the contribution of farming practices toward farmer household food diversity. The study looks at different risk behaviours and how they are linked to incidences of short-term symptoms. Additionally, the study measures the total economic cost of human health impacts attributable to on-farm exposure to farming inputs by estimating treatment costs incurred and wages lost due to loss of productive work days for farmers and farm labourers. Based on regression analysis of the relationship between prevalence of symptoms across farmers and their agricultural practices, the study supports the hypothesis that CNF farming is associated with reduced on-farm health risks and has lower human health impacts compared to chemically intensive farming (reported loss of 121 work days by APCNF farmers and 189 work days by chemical-intensive farming). In terms of economic costs to farmers, the health cost analysis (based on health expenses incurred and wages lost due to illness) showed that average economic loss was highest in villages where chemically intensive farming was practised (almost 26% higher than those for CNF farmers in the same region). Going forward, it is important to address the lack of proper information and awareness in following safe handling and disposal practices – for farmers to mitigate both incidence and economic impacts of health risks due to agricultural input exposure. The HDDS provides interesting insights into the food habits of farmer households surveyed. Average household diet of farmers surveyed has more macronutrient diversity compared to an average Andhra food plate – indicating that these farmer households have access to a wider range of food crops. CNF farmer households consumed higher amounts of fruits and vegetables compared to counterfactual households, which is not surprising given the presence of multicropping practices and kitchen gardens in CNF households. For CNF villages, quality is the biggest driving factor (74%), followed by nutritional content (10%) and price/value for money (9%) when deciding family diet. In comparison, while non-CNF households' diets are also driven by quality (55%), prices played a much larger role (28%) when deciding family diet. A peculiar trend was the corresponding lack in increase in consumption of meat, eggs, and fish in diets, despite increase in household incomes – pointing to the strong role of cultural preferences and habits in determining local diets.

1 Andhra Pradesh Community Managed Natural Farming: An introduction

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1.1 Introduction

Global agriculture and food systems are not on track to meet targets set by Agenda 2030 to achieve zero hunger and eradicate malnutrition by 2030 (FAO, I.U., 2020; Sandhu, 2021). Today, **828 million** people lack access to a sufficient number of calories (dietary energy) on a regular basis, an increase of approximately 150 million since 2019 (FAO, 2022). And an estimated **2.3 billion** people globally (29.3%) were moderately or severely food insecure in 2021, lacking regular access to enough safe and nutritious food for normal growth and development and an active and healthy life – 350 million more than before the outbreak of the COVID-19 pandemic in 2019. Malnutrition in all its forms, including undernutrition (wasting, stunting, underweight), inadequate vitamins or minerals, overweight, and obesity, is growing (TEEB, 2018; FAO, 2020). At the same time, almost 1.9 billion people (39% of the adult population) are overweight; of these, 0.7 billion people are obese (WHO, 2020). In addition, the global burden of disease caused by poor diets continues to increase (GNR, 2020). This is driven, in part, by the inequitable distribution of food and due to the failure of current agricultural practices to produce nutritious food in adequate quantities without risk to ecosystems and society (Sukhdev, 2018; Sandhu, 2019). In recent years, this development has been reinforced by the multiple crises of climate change, the COVID-19 pandemic, armed conflict, and soaring costs (Sustainability, 2023).

Increasingly, the world's food systems will have to deal with dynamic crises, since the current food systems are both causing some of these problems and will be negatively affected. The TEEBAgriFood Framework systematically analyzes the complex interlinkages that are the basis of eco-agri-food systems by identifying the material, yet invisible, links that food systems have with our well-being. We call such links invisible – not because they do not make a visible difference to the quality of our lives, but because current bellwether macroeconomic metrics such as gross domestic product (GDP) and current dominant policies and regulations mostly ignore them, and are instead geared toward only increasing per hectare (ha) productivity (focusing on tons per ha or counting kilocalories and translating them into monetary values).

This study is designed to compare the dominant farming systems prevalent in three very different agroecological regions in the state of Andhra Pradesh, India, with natural farming in each of those three regions. It intends to examine the significant impacts, both positive and negative, of the three systems – chemical-intensive farming, semi-arid rainfed farming, and tribal low-input farming –

compared to the Andhra Pradesh Community Managed Natural Farming (APCNF) system (hereafter CNF).

We need to develop agricultural and food systems that can provide enough nutritious food for all without damaging the environment and human health (Sandhu, 2021). A recent global study supported by the Global Alliance for the Future of Food (GA) and led by the United Nations Environment Programme on the Economics of Ecosystems and Biodiversity for Agriculture and Food (TEEBAgriFood) developed a holistic framework to examine agriculture and food systems so that appropriate policy responses can be developed to fix our broken food systems (TEEB, 2018). This study found that a key feature of today's ineffective food systems was their inappropriate choice of metrics (Sukhdev et al., 2016). There was excessive reliance on productivity per ha of single crops as a yardstick of agricultural performance, without due attention being paid to other significant but economically invisible costs and benefits – so-called externalities – such as impacts on greenhouse gas (GHG) emissions, water scarcity, biodiversity, on-farm and off-farm health, local livelihoods, and employment. This study suggested that one way to develop more appropriate and holistic performance measurement systems is to understand and map all significant impacts and dependencies of current agricultural and food systems on natural, social, and human capital in addition to produced capital, in order to develop more appropriate policies and mechanisms that can deliver truly sustainable farming and food systems.

To promote transitions to farming systems that protect and enhance natural, social, and human capital as well as the production of nutritious food, the GA is supporting an application of the TEEBAgriFood Evaluation Framework to CNF. The study intends to synthesize methodologies that identify the true cost and benefits of CNF by measuring all major environmental, social, and health impacts comprehensively and against widely prevalent local agricultural management approaches as counterfactuals.

High-input farming in the Krishna-Godavari delta region, low-input rainfed farming in the semi-arid southwestern region, and low-input farming in the montane-forested tribal region are compared with CNF in each of those regions in terms of their impacts on natural, social, human, and produced capital. It is believed that this information will help develop recommendations on feasible transitions toward sustainable, effective, just, and equitable food systems.

India has a diverse agricultural sector covering 159 million ha of arable land or 48% of its total land area. This sector is an important part of India's economy. However, the share of agriculture in GDP has declined from 54% in 1951 to 14.8% in 2019 (MoSPI, 2021). Notwithstanding this decline, agriculture and allied activities are an important sector, contributing about USD 271 billion annually and employing approximately 41% of India's workforce (MoSPI, 2021), with Andhra Pradesh showing an even higher employment dependency on agriculture (over 60%). A key feature of India's agricultural sector is that small and marginal land holdings (i.e., with less than 2 ha of land) constitute 85% of the farms in India.

Before the Green Revolution of the 1960s, India's economy was prone to food shortages and acute poverty due to its high dependence on agriculture. Therefore, Indian agricultural policies have

historically been geared toward achieving food self-sufficiency and improving food security through yield intensification. As a result, food grain production in India has increased over four-fold, from 50 megatons in 1950 to 240 megatons in 2018. This productivity growth has been enabled by technology, including intensification of the area under irrigation, use of agricultural machinery, and increases in the application of synthetic inputs – which are associated with significant detrimental impacts on socioeconomic well-being and the environment (Chand, 1998; Swaminathan, 2010; Sandhu, 2021). Much of the agricultural policy framework remains focused on addressing productivity, with an assumption that higher yields will result in higher returns to farmers. However, profits are being realized by agri-businesses, not by the farmers, as is evident from the average income of farmers, which is INR 36,938 for cultivation of crops and INR 9,176 for livestock per year per household, much below the average income from India's non-farm sector (Aayog, 2017).

In the past, agricultural policies have targeted food self-sufficiency and food security with much less emphasis on farmers' well-being. While it is vital to continue to produce a more diverse range of healthy foods for a growing population (as a foil for the narrow range of carbohydrate-heavy staples available), it is also important to consider other aspects related to farming, such as farmers' well-being and the health of farmers and farm workers; working conditions; the state of women farm workers and landless labourers; and the protection of land, soil, and water resources that are critical for the future health, resilience, and performance of farms and hence for the overall well-being of farmers, their families, and rural communities.

1.2 Rationale

In addition to some challenging agricultural policies, risks due to climate change, biodiversity loss, loss of groundwater, soil degradation, farmers' and farm workers' health, women workers' conditions, and chronic malnutrition are just some of the issues not currently addressed by the most widespread models of Indian agriculture. These risks are now undermining the ability of farmers to produce enough nutritious food for India's vast population. This report not only analyzes these risks but also presents an assessment of alternative production systems that can cope with these escalating challenges. And TEEBAgriFood provides the analytical framework used in our evaluation.

The Zero Budget Natural Farming (ZBNF) system, started in Karnataka and Andhra Pradesh (two large states in India) is one such promising alternative to high-input farming in India. It started as a peasant-led social movement to uplift debt-ridden farmers who adopted high-input chemical-based farming during the Green Revolution of the 1960s. To overcome these problems, agroecology-based farming gained attention over the last several decades and is now being practised by millions of farmers in Karnataka and Andhra Pradesh.

In Andhra Pradesh, this model has evolved further and is described as Community Managed Natural Farming (or APCNF; see http://apzbnf.in). The farming practices of APCNF include production of sufficient and diverse types of food by managing soil fertility through crop rotations, bioremediation of soils, and natural pest controls to manage diseases and pests. It is an impressive example of taking agroecology to scale through government support and policy shifts (Khadse, 2018 and 2019). Many governments, including the Indian government, are interested in the approach. However, scientific

literature that compares all the costs and benefits of APCNF with other prevalent farming systems is limited. This present study intends to evaluate APCNF for its impacts and dependencies on social, human, and financial capitals, to provide evidence to encourage a broader global uptake of this approach.

1.3 Agricultural production systems

India is geographically and culturally a very diverse country, and this diversity is reflected in the spectrum of food production systems practised in different parts of the country. India is divided into 15 agroclimatic zones and 20 agroecological regions (based on various indicators), and these regions are suitable for certain ranges of crops and livestock. Table 1 provides a summary of India's major farming systems.

Table 1: Summary of farming systems in India

Farming system	Description	Scale
Low input	Farming methods with low levels of input and output. The inputs are mainly seed, animal power for cultivation, simple machinery such as plows, and human labour. It comprises a restorative phase of pasture or legumes between phases of crop cultivations.	Small, local
Tribal farming	Traditional farming methods with low levels of input and output. Food produced is primarily for self-consumption.	Small, local, forest margins
Shifting cultivation	Includes clearing of land for temporary cultivation followed by a long restorative phase to stimulate soil fertility.	Small to medium, regional, forest margins
Natural farming	Community-based farming that manages soil fertility and moisture with bio-remediation through the addition of farmyard residues, constant mulching, and cyclically growing diverse local varieties of crops and livestock.	Small, local
High-input cropping	Utilizes high levels of input, such as pesticides, fertilizers, improved seeds, irrigation, and heavy machinery, while producing high levels of output.	Small to large
Mixed crop-livestock	An integrated farming system where crops and livestock are raised on the same farm.	Small to medium

Perennial	Includes the cultivation of crops, fruit trees, groves, and plantations whose life cycle is longer than 2 years.	Medium to large
Organic farming	Avoids use of synthetic fertilizers, herbicides, and insecticides. Depends on a few natural external inputs and regulates the farm to enhance soil fertility and biodiversity.	Small to large
Zero Budget Natural Farming	Promotes natural growth of crops without adding any fertilizers and pesticides or any other foreign elements. "Zero Budget" refers to the zero-net cost of producing all crops (inter crops, border crops, multicrops) by avoiding chemical inputs.	Small to medium

Andhra Pradesh has about 9 million ha of arable land that spans the agroclimatic zones from the hills to the eastern coastal plains. Agriculture plays an important role in the economy of Andhra Pradesh state, as it contributes approximately 33% to the gross state product (Directorate of Economics and Statistics Andhra Pradesh, 2019). Over 60% of its population is gainfully employed in farming, and 13 districts produce a variety of crops, such as paddy, jowar, maize, bajra, finger millet (ragi), groundnut, pulses, fruit, vegetables, oilseed, and other commercial crops.

1.3.1 Agroecology in action

Agroecology is defined as the interaction between farm, people, and other living species by using the principles of ecology (Altieri, 1995; Sandhu, 2021). It has 10 basic elements: diversity, synergy, recycling, efficiency, resilience, circular economy, co-creation of knowledge, responsible governance, human and social values, and culture and food systems (FAO, 2021). It does not recommend one practice over another in growing food. It promotes four dimensions of food sustainability: environmental, economic, social, and agronomic. There is a focus on the diversification of food systems to improve soil health and biodiversity.

APCNF builds on the principles of agroecology and is being adopted by a growing number of small-scale farmers in Andhra Pradesh (from 176,000 in 2005 to 630,000 in 2021/22) (RySS, 2021). It has the potential to be scaled up at country and regional level.

1.4 Description of CNF

CNF is a farming practice that depends on the natural growth of crops without the use of any synthetic fertilizers and pesticides and with less consumption of ground water. It has dramatically reduced the net cost of production, as there are additional gains to farmers by growing inter crops, border crops, multicrops, etc. The few significant inputs – cow dung, cow urine, handfuls of soil, jaggery, pulses flour, and botanicals for bio pesticides – used for seed treatments and soil inoculations are all locally available (RySS, 2021).

CNF has its roots in the Zero Budget Natural Farming (ZBNF) system pioneered by Mr. Subhash Palekar, who is regarded as the father of ZBNF. He started natural farming on his own land in the 1970s, and his practices were standardized over time through adoption by other farmers in Maharashtra, Karnataka, and Andhra Pradesh. Today, ZBNF has practitioners in virtually all the states in India.

1.4.1 Principles & practices of CNF

CNF practices are based on the nine key principles described below (RySS, 2021).

1) Covering soil in crops 365 days a year (living root).
2) Disturbing soil only minimally.
3) Using natural biostimulants as necessary catalysts to achieve good health for soil biota, such as microbial seed coating by cow urine and dung-based formulations, and revitalizing the soil microbiome through inoculum of cow urine, cow dung, and other ingredients. (According to Mr. Palekar, one cow is enough to cultivate 12.14 ha, since cow dung is not used as a bio-fertilizer but an inoculum.)
4) Choosing indigenous seeds.
5) Growing diverse (15 to 20) crops and trees.
6) Integrating animals in farming.
7) Increasing organic residues in soil: Building soil humus using good farm practices to improve soil aeration and harness water vapour.
8) Managing pests through botanical extracts.
9) Avoiding synthetic fertilizers, pesticides, and herbicides (all inputs to be sourced within the village).

Based on these principles, CNF's focus is on:

- Reducing costs of cultivation, reducing risks, and increasing yields, thereby generating regular incomes and making agriculture more climate resilient.
- Producing more safe and nutritious food that is free of chemicals.
- Reducing the migration of youth from villages to urban areas and creating reverse migration to villages.
- Enhancing soil health and water conservation, and regenerating coastal ecosystems and biodiversity.

CNF has shown tremendous traction across the state of Andhra Pradesh in the past 5 years (see Table 2).

Table 2: Number of villages and total number of farmers practising CNF in Andhra Pradesh

	Parameter	2018–19		2019–20		2020–21		2021–22	
		No. of farmers	**Area in ha**	**No. of farmers**	**Area in ha**	**No. of farmers**	**Area in ha**	**No. of farmers**	**Area in ha**
1	**Total no. of villages**	**2,005**		**2,005**		**3,730**		**3,730**	
2	**No. of practising CNF farmers**	**176,504**	**93,175**	**44,1953**	**179,514**	**478,844**	**202,652**	**630,441**	**288,898**
3	**No. of 100% chemical-free farms**	**33,124**	**19,485**	**88,390**	**37,698**	**128,304**	**53,384**	**25,5319**	**111,026**

Source: RySS, 2021.

1.5 Objectives of this study

This study intends to generate a proof-of-concept for a sustainable and equitable farming system by evaluating CNF using a comprehensive, universal, and innovative framework developed by the UNEP in partnership with the Global Alliance for the Future of Food. Using the TEEBAgriFood Evaluation Framework, we compare CNF with the dominant type of farming systems in each of the three agroecological zones of Andhra Pradesh.

The specific objectives of the study are:

Objective 1: To synthesize and demonstrate methodology that compares diverse production systems, measuring the economic, social, and health impacts of CNF in Andhra Pradesh.

Objective 2: To describe (and monetize, where possible) all dependencies, impacts, and externalities (positive and negative, including economic, social, and health externalities) through a comparison of CNF against three counterfactuals, i.e., the three types of production systems most prevalent in each region (low-input rainfed, high-input delta, and low-input tribal farming regions).

Objective 1 is achieved by developing and testing a framework based on the TEEBAgriFood study. It elaborates on four capitals relevant to agri-food systems and specific to the target agroecological regions and farming systems.

Objective 2 is achieved by conducting primary studies that include crop-cutting experiments to evaluate yields and household surveys to examine the economic, social, and health impacts across three agroecological regions where CNF is compared to an alternative farming system.

2 Framework & methodology

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Take-home messages

1) The TEEBAgriFood Framework identifies the links between food production and human health, demonstrating that productivity per ha alone is not a reliable indicator.
2) The TEEBAgriFood Framework identifies four fundamental and interconnected elements that can be generalized across all agriculture and food systems: stocks, flows, outcomes, and impacts.
3) The TEEBAgriFood Framework is used to assess and compare Community Managed Natural Farming (CNF) with three farming systems: tribal, semi-arid agriculture systems, and chemical-intensive systems in the Godavari delta area (see Tables 4 to 11).

2.1 TEEBAgriFood Evaluation Framework

The TEEBAgriFood Evaluation Framework is intended to systematically identify the material yet invisible links between our food systems and our well-being – "invisible" not because they do not make a visible difference to the quality of our lives, but because current dominant policies and regulations are geared toward only increasing per hectare (ha) productivity (Obst, 2018). This focus not only ignores important links but, as Chapter 1 illustrates, places an emphasis on narrow goals that lead to perverse outcomes for the environment and our health. For example, instituting policies that focus on increasing yields without an examination of how these yields contribute to – or are related to – access to food and nutrition are incomplete in both their assessment and, consequently, their prescription.

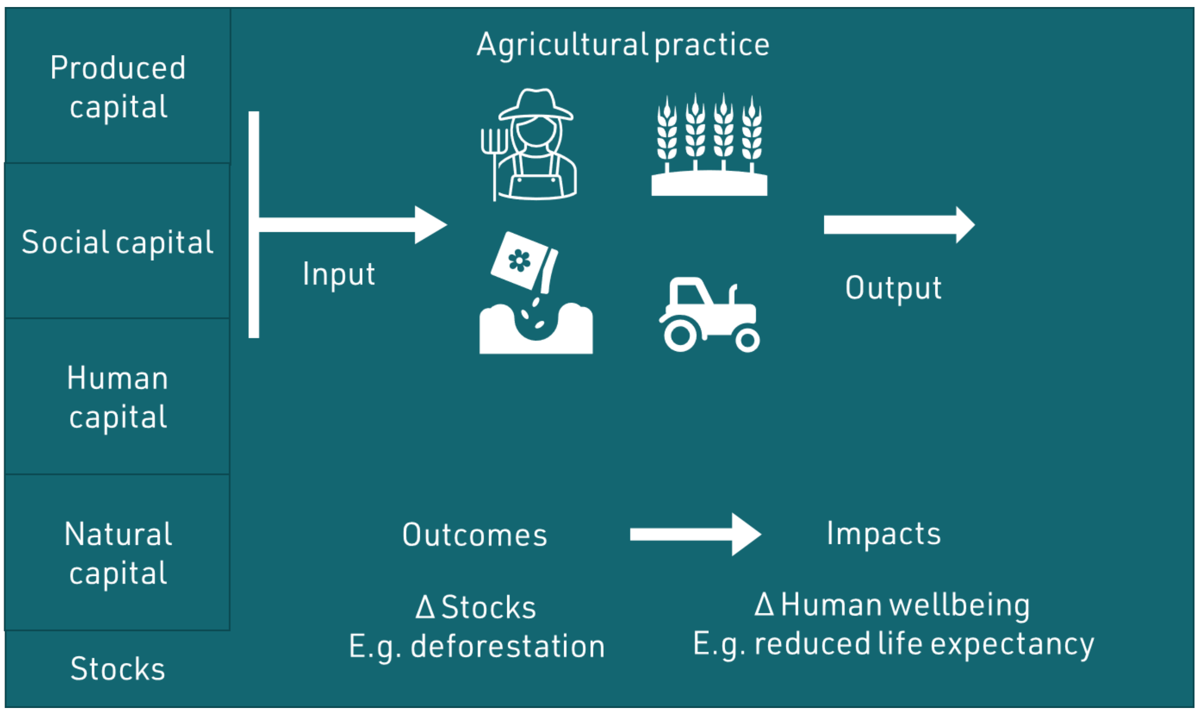
The agricultural systems considered as part of this study are rich in terms of the connections they have with all four capitals – human, social, produced, and natural. They have evolved alongside each other in similar regulatory, policy, and environmental contexts, yet they are different in terms of their social, human, economic, or environmental footprint. As the SDGs acknowledge, sustainability of environmental outcomes is closely tied to goals of eradicating poverty, providing nutrition and food security. A transformation of our agricultural systems can therefore potentially present several opportunities to work toward these connected goals. To be able to do this, we need to understand and talk about these systems differently – make visible these invisible connections and understand both the social and political context within which these systems operate and their historical evolution. This kind of assessment can bring to light the systems we want to encourage to meet the SDGs and the potential pathways for us to get there.

The TEEBAgriFood report highlighted the need for a common framework to take a systems approach and systematically organize the generalizable components of agri-food systems (TEEB, 2018). The Framework is meant to include all relevant social, human, environmental, and economic links – of and within – agri-food systems (i.e., be comprehensive), to be both quantitative and qualitative (inclusive), and be available in a common language that can be used across different systems (universal).

2.2 Framework

To account for all relevant connections within agri-food systems in a systematic manner, the Framework identifies four fundamental yet interconnected elements generalizable to all agriculture and food systems: stocks, flows, outcomes, and impacts (see Figure 1).

Figure 1: Stocks, flows, outcomes, & impacts



Source: Compiled by authors.

2.2.1 Stocks

"Stocks" are the quantities and qualities of (natural, human, social, produced) capital within a system at a point in time. "Natural capital" refers to the limited stocks of physical and biological resources found on Earth. "Human capital" refers to the knowledge, skills, competencies, and attributes embodied in individuals. "Social capital" includes networks, including institutions, that share norms, values, and understandings. Lastly, "produced capital" includes manufactured capital, such as buildings, factories, machinery, and physical infrastructure, as well as all financial capital and

intellectual capital. The condition (quality) and extent (quantity) of these capital stocks underpin or are affected by several of the flows in our Framework.

2.2.2 Flows

"Flows" are costs or benefits derived from use of capital in the agri-food value chain and are categorized broadly as "inputs" and "outputs." In the Framework, inputs include purchased resources (labour, energy, water, etc.), and ecosystem services (nutrient cycling, pollination, etc.). Outputs include agricultural and food resources in the form of goods and services (including food products, and financial outputs, such as income, taxes, and subsidies) and residuals that arise from their production (GHG emissions, excess nitrogen, harvest losses, and food waste).

2.2.3 Outcomes

"Outcomes" are the positive or negative changes in the extent (quantity) and/or condition (quality) of stocks of capital. Changes in capital can result from the employment (use) of capital (depreciation) and the management of capital (e.g., investment in capital improvement, buying new capital, and repurposing capital). It is also possible for capital to be degraded because of residuals (e.g., the flow of agricultural run-off into a river — natural capital) or other shocks (e.g., fire).

2.2.4 Impacts

"Impacts" are changes in well-being that are connected to outcomes (a change in capital). Impacts can be categorized into four types: environmental, economic, health, and social impacts. Impacts can be described as increases in services (quantity effect), changes in price, increases in disservices, increases in costs, reduction in costs, changes in risk levels (which can be expressed in changes in costs or services or expectations), and changes in the distribution of these costs and services. For example, poor soil management may lead to desertification (an outcome). The impact linked to this outcome is a loss of income for a farmer, which in turn may lead to higher stress and a decrease in their quality of life. Impacts are measured by valuing the changes (projected or observed) associated with an activity or intervention.

2.3 Approach

The TEEBAgriFood Evaluation Framework is supported by TEEBAgriFood Implementation Guidance (Eigenraam, 2020; Coalition, 2020). The Guidance contains four phases of implementation: frame, describe and scope, measure and value, and take action. Each phase entails several steps that practitioners can perform to complete an agri-food system assessment (see Table 3). Applying the four phases and related steps can bring structure to your study; more information on how to apply the four phases can be found in the Implementation Guidance.

Table 3: Implementation Guidance phases and steps

Phase	Explanation
Phase 1: Frame	Frame the issue of interest and the purpose of your assessment, and prepare to undertake it. Important components of this phase include identifying relevant stakeholders, forming an advisory committee, and outlining your plan of action.
	Step 1: Outline your interest. Step 2: Determine the issue of interest. Step 3: Clarify the purpose. Step 4: Identify stakeholders and form an advisory committee. Step 5: Outline an action plan for your results.
Phase 2: Describe & scope	Describe the relevant agri-food system and the scope and focus of the assessment using an integrated process. This ensures that all connections and impacts relevant to the assessment are identified before determining their relative importance.
	Step 6: Describe the system. Step 7: Describe the agri-food value chain. Step 8: Describe the activities of interest. Step 9: Describe the capital stocks. Step 10: Describe the flows. Step 11: Describe the outcomes. Step 12: Describe the impacts. Step 13: Assess materiality. Step 14: Select impacts for assessment. Step 15: Identify opportunities for change.
Phase 3: Measure & value	Measure impacts using a selection of models, methods, and data. Where relevant and possible, you will also value or monetize these impacts. The TCA Inventory (TMG, 2020) has been developed to support this process.
	Step 16: Select an analytical approach and method. Step 17: Select appropriate variables and indicators. Step 18: Collect data and measure. Step 19: Apply value to your measurement. Step 20: Validate your study and test key assumptions.
Phase 4: Take action	Apply the results of your assessment with stakeholders and partners to take action and ensure your assessment has an impact on practice and policy.
	Step 21: Identify who is affected. Step 22: Apply and act on your results. Step 23: Communicate your results.

2.4 Applying the Evaluation Framework

This study uses the TEEBAgriFood Evaluation Framework to assess and compare CNF with other farming systems, namely tribal farming systems, dryland or rainfed agriculture systems, and chemical-intensive systems. Use of the Framework supports the systematic accounting of how these farming practices depend on multiple capitals, and lead to different outcomes and impacts in three different districts in the state of Andhra Pradesh, India: Vizianagaram, Anantapuramu, and West Godavari. These three districts span three different agroecological zones. Within each district, agricultural practices of CNF are assessed alongside non-CNF practices, such as tribal agricultural practices in the montane-forested region, low-input practices in the rainfed semi-arid region, and chemically intensive practices in the Krishna-Godavari delta region. Examining multiple agroecological zones can help us understand the applicability of principles of agroecology to different contexts.

Each of these practices present different relationships with the four elements of the Framework.

2.4.1 Stocks & flows – Community managed natural farming

The practice of farming depends on the natural capital stock of soil. To ensure the quality of this stock, inputs of bio stimulants (such as those based on the fermentation of animal dung and urine, and uncontaminated soil) are necessary to catalyze the process. Furthermore, crop residue mulch must be maintained throughout the year to support a healthy soil structure and microbiome. This nutrient-rich environment promotes effective nutrient cycling and carbon storage in the soil. To minimize soil disturbance, CNF practises no-till farming or shallow tillage, ensuring carbon storage. This type of system also supports habitat-related services (for pollinators) since it promotes diversity of crops. By focusing on mixed cropping and intercropping, along with the integration of livestock, this system promotes resilience, both in ecological (pest outbreaks) and social terms (other sources of food and income). Indeed, pest management is supported by agronomic practices, and botanical pesticides are used only when necessary. The impacts of the lack of synthetic chemicals ensure that the flows resulting from the systems (in terms of run-off) are minimal (although nutrient run-off to nearby waterbodies may be an issue).

The relationships between these farming practices and human health are also important. The absence of synthetic farm-level inputs means farmers avoid exposure to dangerous chemicals. Furthermore, growing a wide range of crops to support local consumption positively impacts nutrition and food security. Lastly, this system needs very little financial credit and reduces the dependency of farmers on moneylenders and institutions.

Table 4 and Table 5 summarize this discussion, using the four elements of the Framework (stocks, flows, outcomes, and impacts) to demonstrate its application.

Table 4: Inputs & outputs from CNF

Inputs		**Outputs**	
Purchased inputs (Produced capital)	**Ecosystem services (Natural capital)**	**Residuals**	**Agricultural outputs**
• Machinery • Biostimulants – No synthetic fertilizer or pesticide • Labour intensive at beginning of project, then labour use similar to chemical-intensive farming • Women regularly employed • Credit requirement is low, relative to other systems • Inputs made by the farmers themselves or purchased within the village	• Provisioning services • Carbon sequestration and storage in soil and vegetation • Supporting services – Biodiversity	• CO_2 emission from machinery use (natural capital impacts)	• High-quality crops (human capital impacts) • Quantity of output (produced capital and human capital impacts) • Wages for labour (produced capital impacts)

Source: Compiled by authors.

Table 5: Outcomes & impacts from CNF

	Produced	**Natural**	**Human**	**Social**
Outcomes	• High yield	• Increased soil fertility • Reduced carbon in atmosphere	• Improved nutrition	• Improved networks between farmers • Increased engagement of women • Local consumption and less dependence on food markets
Impacts	• Decreased fiscal costs of production	• Increase in public ecosystem services (carbon, biodiversity)	• Higher quality of life (due to improved nutrition)	• Higher levels of gender equality

Source: Compiled by authors.

2.4.2 Stocks & flows – Chemical-intensive farming in the delta region

These farming practices continue at large and are supported by public subsidies for fertilizers, pesticides, and irrigation. Despite public support in the form of subsidies, the system relies heavily on external inputs, and farmers tend to depend on continuous access to credit to be able to turn a profit. Furthermore, loss of ecosystem services such as nutrient cycling, poor soil structure, and soil degradation re-enforce the continuous use of external inputs. The system is high-till and results in long-term effects of soil compaction, lack of soil structure, and a poor soil biome. The off-farm effects

of this kind of farming, particularly nutrient and pesticide run-off, have been well documented, and on-farm impacts include health of farmers, labourers, and families. The magnitude of the latter, however, also depends on the kind of information and training farmers receive on handling chemical inputs as well as their use and disposal.

In terms of social capital, while farmer support systems may exist, farmers are dependent on the market for inputs, money-lending institutions for credit, agriculture experts, and input shop dealers for technical advice, and are susceptible to commodity price fluctuations (particularly if commodities produced are for extra-local consumption or include cash crops). These may result in lower social resilience and lower levels of trust within the community.

Table 6 and Table 7 provide a summary of this discussion, using the four elements of the Framework (stocks, flows, outcomes, and impacts) to demonstrate its application.

Table 6: Inputs & outputs – Chemical-intensive farming

Inputs		**Outputs**	
Purchased inputs (Produced capital)	**Ecosystem services (Natural capital)**	**Residuals**	**Agricultural outputs**
• Chemical intensive – Fertilizer • Labour requirements initially lower than CNF • Credit requirements are very high, leading to indebtedness on the part of the farmers (90% of farmers are in debt) • Groundwater extraction	• Provisioning services • Some carbon sequestration and storage, but less than CNF • Supporting services typically weaker than CNF system • Low groundwater table	• Run-off • Chemical air particles • CO_2 emissions from machinery use • CO_2 released from tilling	• Food quality is poor (in terms of nutrition) compared to CNF (human capital impacts) • High quantity of output (produced capital impacts) • Wages for labour (produced capital impacts)

Source: Compiled by authors.

Table 7: Outcomes and impacts – Chemical-intensive farming

	Produced capital	**Natural capital**	**Human capital**	**Social capital**
Outcomes	• Medium to high production	• Soil degradation and depletion • Increased carbon in atmosphere • Reduced biodiversity • Degradation of river health • Reduced groundwater levels	• Reduction in health of farm workers due to exposure to chemicals	• Low levels of trust within the community

Impacts	• High fiscal costs of production	• Reduction in public ecosystem services • High short-term biomass provisioning services • Low long-term biomass provisioning services	• Increased health costs	• Low resilience • High risk

Source: Compiled by authors.

2.4.3 Stocks & flows – Low-input farming in semi-arid region

There are three components of a successful dryland farming system: 1) retaining the precipitation on the land, 2) reducing evaporation from the soil surface to increase the portion of evapotranspiration used for transpiration, and 3) utilizing crops that have drought tolerance and that fit the precipitation patterns (Stewart, 2016).

Conditions of moderate-to-severe moisture stress occur during a substantial part of the year, greatly limiting yield potential, and during which farmers emphasize water conservation in all practices. Semi-arid rainfed systems are related but not equivalent to the delta area agricultural systems. Semi-arid systems are low input since they do not use chemical products. In terms of water efficiency, the system could be highly efficient, particularly if using water-saving techniques. Since it is a low-input system, there is less dependence on credit, although it may be important to assess social capital factors such as cooperation between farmers, in terms of knowledge of farming practices, rainwater harvesting, seed sharing, and lending practices. Furthermore, seasonal variability in rainfall can make these systems risky, and farmers usually look for work outside their villages during the dry season.

Table 8 and Table 9 provide a summary of this discussion, using the four elements of the Framework (stocks, flows, outcomes, and impacts) to demonstrate its application.

Table 8: Inputs & outputs – Dryland agriculture

Inputs		**Outputs**	
Purchased inputs (Produced capital)	**Ecosystem services (Natural capital)**	**Residuals**	**Agricultural outputs**
• Low input use • No credit	• As for CNF • High dependence on rainwater	• As for CNF	• Wages • Low productivity

Source: Compiled by authors.

Table 9: Outcomes & impacts – Dryland agriculture

	Produced capital	Natural capital	Human capital	Social capital
Outcomes	Low production	• Soil nutrients maintained due to intercropping and multicropping • Higher levels of farm diversity	• Seasonal employment in agriculture can create precarity	• Lower cohesion due to seasonal migration of workers
Impacts	Low income	• Low impact on water stocks • Habitat services • Low impact on soil health	• Mental health impacts	• High risk of low return from agricultural activities

Source: Compiled by authors.

2.4.4 Stocks & flows – Low-input farming in montane-forested tribal region

These systems use very little or no pesticides but may sometimes use high levels of fertilizers. The farmers depend on forest mulch, which is an important input for soil health. Tribal farming systems also do not depend too much on money-lending institutions, and farming is done as part of a community where links between families are important. Farming supports a wide variety of crops and vegetables, mostly for self-consumption. Furthermore, the labour requirements of this system are lower, which may allow for more leisure time.

Table 10: Inputs & outputs – Tribal farming systems

Inputs		**Outputs**	
Purchased inputs (Produced capital)	**Ecosystem services (Natural capital)**	**Residuals**	**Agricultural outputs**
• Low levels of purchased inputs, except for fertilizers • Similar to CNF system in terms of cost and credit • Labour required is less than CNF, and there is labour-sharing • High engagement of women in farming	• Forest ecosystems (NTFP) used to complement agricultural systems output • Cultural services from forest • Similar to CNF	• As for CNF • Nutrient run-off	• Food production for self-consumption

Source: Compiled by authors.

Table 11: Outcomes & impacts – Tribal farming systems

	Produced capital	Natural capital	Human capital	Social capital
Outcomes	• Low levels of commercial crops	• Lower water quality due to eutrophication • Greater farm diversity	• Improved nutrition	• Greater participation of women in farming
Impacts	• Low income	• Higher habitat services provisioning	• Higher quality of life (due to improved nutrition)	• Higher levels of gender inequality • Increased time savings for other social activities

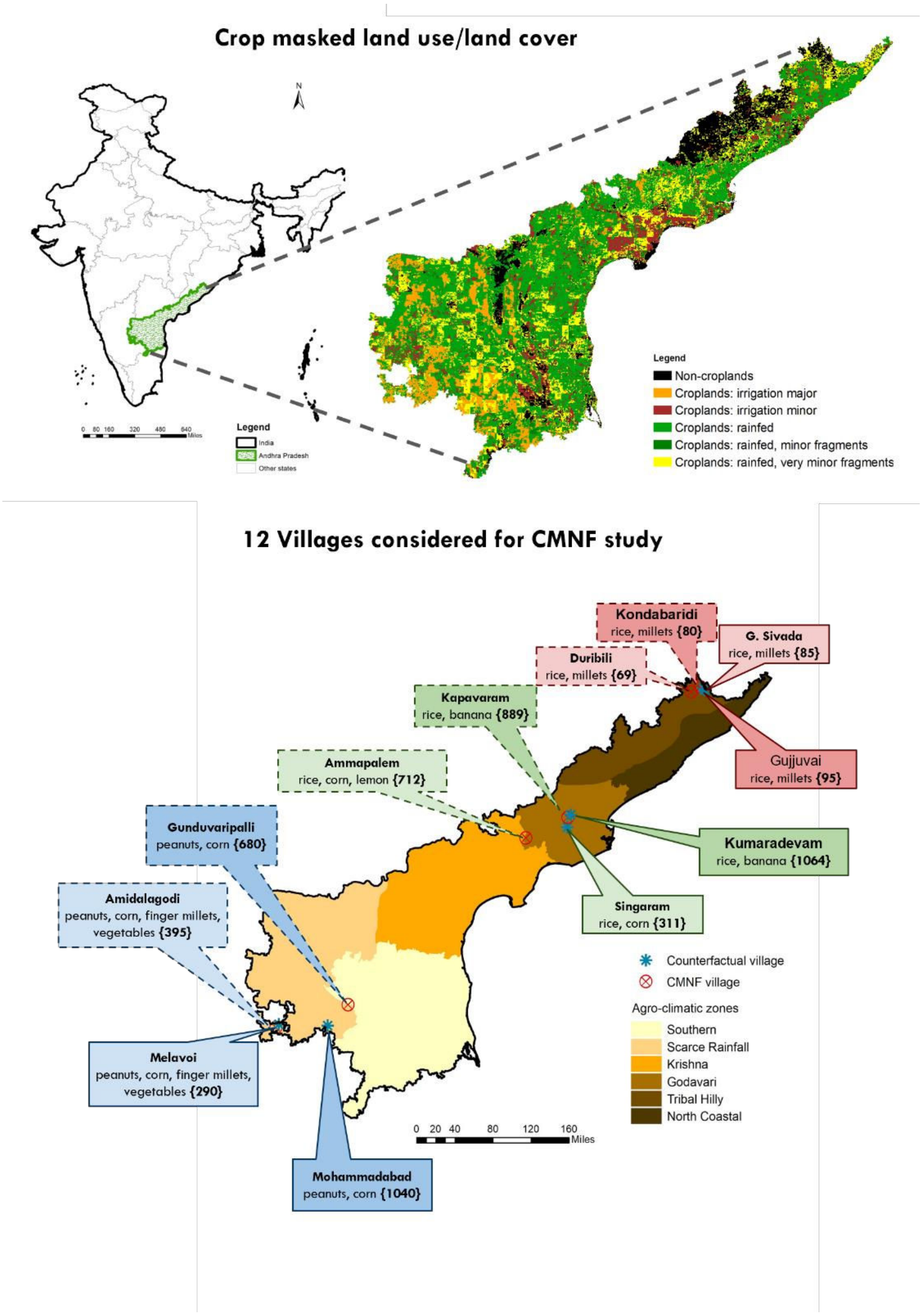
Source: Compiled by authors.

2.5 Data sources & profiles of study villages

The data for this study is based on primary studies that include crop-cutting experiments to evaluate yields in 13 districts and also a large primary survey carried out during 2020–2022 in West Godavari, Vizianagaram, and the Anantapuramu districts of Andhra Pradesh, where CNF is actively practised. A questionnaire survey has been administered to 562 farming households in 12 villages, 4 villages each in East Godavari, Vizianagaram, and the Anantapur districts of Andhra Pradesh (see Figure 2 and Table 12). Table 26 provide sociodemographic and socioeconomic characteristics of these villages (see Chapter 4).

These sites were chosen to mirror different agroecological conditions and different livelihood conditions. For each district, two villages with active CNF and its counterfactual have been taken.

Figure 2: Map of Andhra Pradesh, with the 12 villages and their main agricultural products



Source: Government of India, Global Food-Support Analysis Data 2010 (1 km). Platform: Google Earth Engine.

The villages of Durbili, Gujjuvai, Kondabaridi, and G. Sivada belong to Vizianagaram District of Andhra Pradesh. These four villages are tribal villages in hilly terrain whose main food crop is paddy and millet. The average land holdings varied between 1.21 to 2.7 ha per household. Cashew is the main cash crop in this village, and paddy is mainly cultivated in these villages as kharif crop. The four villages have very active women farming communities. Of these villages, Kondabaridi has been declared the first village in Andhra Pradesh to have adopted 100% ZBNF.

The second two sets of villages are chosen from the Anantapur District of Rayalaseema (villages of Melavoi, Amadalagondi, Gunduvaripalli, and Mohammadabad). All these villages have a slopy terrain and belong to the scarce rainfall zone. The main food crops in these villages are groundnut, vegetables, maize, and finger millet (ragi). Mulberry, chrysanthemum, and areca nut are grown as cash crops in two of these villages. Women farmers are moderately active, and more than one self-help group (SHG) is active in these villages.

The third group of villages (Ammapalem, Singaram, Kapavaram, and Kumaradevam) is chosen from the West Godavari District in the fertile Krishna-Godavari climate zone and receives good rainfall. The villages predominantly grow paddy. Guava, coconut, maize, and banana are the main cash crops of the region. Food crops grown include paddy, corn, lemon, maize, and plantain.

2.5.1 Sample size & data collection

We have used two sources of data in the analysis: crop-cutting farm data from 2017–18 (1,828 farms, 34 villages) and rural survey data gathered in 2020–21 to assess the impacts of CNF adoption (562 farmers, 12 villages). Household survey was conducted by on-ground data partner 7L Consultancy in collaboration with RySS (Rythu Sadhikara Samstha). Random sampling was applied to determine the sample households within a village to be surveyed. See Table 14 for details on the sample size and study area. A total of 562 questionnaires were completed and analyzed as part of the study. The three chapters included as part of this report each examined a particular component of these systems, using extensive surveys and field studies.

Chapter 3 used both field studies and surveys to assess the economic dimensions of the various farming systems, and how these change as CNF practices are adopted (see Table 22). Field studies on crop cuttings were used to estimate changes in productivity, yields, and income, and surveys were used to assess farm size, women and labour force participation rates, access to capital, irrigation infrastructure, etc. (see Table 14). These were also used to understand how the variables may be related to adoption of CNF practices.

Chapter 4, on social capital, used surveys to capture three dimensions of social capital – structural, cognitive, and relational. The survey included questions on levels of trust among various stakeholders, farmers' perception regarding benefit from being part of the group, level of information sharing, collective action and cooperation among the farmers, and social cohesion. Table 22 lists the indicators used to estimate the differences in social capital across the various farming systems.

Chapter 5 used surveys to collect quantitative data regarding agriculture practices of farmers and dietary practices of farming households (see Figure 16). Data was collected on perceptions regarding

different farm inputs, land preparation methods and techniques, immediate short-term symptoms observed after use of different farm inputs, chemical poisoning and disease information, and changes observed prior to and after adoption of CNF practices. The diet and nutrition questionnaire were designed based on household dietary diversity score (HDDS) to reflect, in snapshot form, the economic/social ability of a household to access a variety of foods

Table 12: Details of study area, farmer sample size, & key crops studies in current assessment

Agroecological zone	Average annual rainfall (mm)	District	Cluster	Village name	Main farming practice	Total households (HH)	HH sample size	Main crops cultivated
Tribal hilly zone	1,000	Vizianagaram	Mantinavalasa	Durbili	CNF	69	24	Paddy and millets
	1,000		Outside of cluster	Gujjuvai	Default organic	85	24	Paddy and millets
	1,000		Kondabaridi	Kondabaridi	CNF	80	24	Paddy and millets
	1,000		Outside of cluster	G. Sivada	Default organic	95	24	Paddy and millets
Low-rainfed region	360	Ananthapuram	Melavoi	Melavoi	CNF	395	68	Groundnut, vegetables, maize, finger millet (ragi)
	360		Melavoi	Amidalagondi	Dryland/ rainfed	290	66	Groundnut, vegetables, maize, finger millet (ragi)
	440		Gunduvaripalli	Gunduvaripalli	CNF	680	50	Groundnut and maize
	440		Gunduvaripalli	Mohammadabad	Dryland/ rainfed	1,040	50	Groundnut and maize
Krishna-Godavari	990		Koppaka	Ammapalem	CNF	712	76	Paddy, corn,

basin climate region		West Godavari						maize, lemon
	990		Koppaka	Singaram	Chemical intensive	311	58	Paddy and maize
	1,100		Dharmavaram	Kapavaram	CNF	889	40	Paddy and maize
	1,100		Dharmavaram	Kumaraevam	Chemical intensive	1,064	58	Paddy and maize
Total HH sample size							**562**	

Source: Author's compilation; see

https://www.mines.ap.gov.in/miningportal/downloads/applications/west%20godavari.pdf.

3 Economic dimensions of CNF: Outcomes for farmers & communities in different districts & agroecosystems

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Take-home messages

1) CNF is a type of redesigned agricultural system, and as such it builds natural, social, and human capital. Indeed, redesign requires three important shifts to occur: in knowledge systems, farming communities, and supporting institutional architectures.
2) We quantify how much CNF improves farming in Andhra Pradesh's different climatic areas, according to different indicators.
3) In Study 1, we look at yield production and net income. The average yield increase associated with the adoption of CNF ranges between 7.8 to 25.9%.
4) In Study 2, we look at the economic outcomes of CNF. The main outcomes of the adoption of CNF are:
    a) Average increase in **crop diversity** from 2.1 to 4 crops per farm.
    b) Increased **labour requirements** (up 21%), which is not necessarily a problem depending on farm labour availability and capacity to pay for local labour.
    c) Lower **input costs**, falling by 44% on an average in the entire study area.
    d) The **gross income per farm** more than doubles in the semi-arid area; no significant difference is registered for tribal farmers, while it falls significantly in high-input systems of the Godavari delta area. However, gross income per ha increases significantly by USD 684 (+28.3%) overall with the adoption of CNF across three regions. It increases significantly in the high-input farming of the Krishna-Godavari delta region by USD 1,728 per ha (+42.3%).
    e) Following this, **net income per farm** is also significantly higher on tribal and semi-arid areas CNF farms (by USD 832 per farm in the semi-arid area and by USD 419 in the tribal area). However, high-input CNF farmers in the Godavari delta area have a lower net income compared with non-CNF farmers. Net income per ha doubles with the adoption of CNF by USD 1,177 (+99.1%) across three regions. The highest increase per ha is recorded in in the high-input farming of the Krishna-Godavari delta region by USD 2,401 (+104.5%), followed by the semi-arid southwestern region by USD 404 (+88%).
5) Farm costs fell on 77% of farms, most markedly on farms in the semi-arid area, where 87% of CNF farmers reported improvements. Similarly, farm income improved on 67% of farms.

3.1 CNF and the importance of agricultural system redesign

Worldwide, sustainable agriculture approaches have also been shown to increase productivity, raise system diversity, reduce farmer costs, reduce negative externalities, and improve ecosystem services (Sandhu et al., 2007). All sustainable transitions require investments to build natural, social, and human capital: such redesign is not costless. Recent global assessments of sustainable intensification have showed that projects and initiatives in some 100 countries containing 163 million farms are using sustainable methods on an area approaching 453 million hectares (ha) of agricultural land (Pretty, 2006 and 2018a). This comprises 29% of all farms worldwide; and 9% of agricultural land (total worldwide land for crops and pasture is 4.9 billion ha). In every case, social capital formation leading to knowledge co-creation has been a critical pre-requisite (Pretty, 2020). Also, farmer benefit (such as food output, income, health) was demonstrated and understood.

Redesigned agricultural systems achieve synergies between ecosystem health and farm operations. The potential for these synergies has been noted around the world and is encapsulated in approaches as diverse as agroecology, regenerative systems, and sustainable intensification, all of which take a pragmatic approach to rejuvenating the environmental and social basis of agriculture (Hill, 1985; Gliessman, 2005; Pretty, 2018a). In other words, they are not prescriptive, recognizing that no single or standardized form that can achieve sustainability across all farms, or even over time. Examples of specific interventions that can be viewed as redesign include crop varietal improvements, multicropping, integrated pest management, conservation agriculture, the system of rice intensification (SRI), the intensification of small patches of land, and CNR. Each of these has the potential to achieve positive synergies between yields, farm resilience, and wider ecosystem and social benefits (Pretty and Bharucha, 2014; Pretty and Williams, 2011).

Redesign requires three important shifts to occur in knowledge systems, farming communities, and supporting institutional architectures. First, knowledge systems need to broaden, away from the simplified technical aspects of high-throughput agriculture, and include context-specific knowledge of whole agroecosystems, and knowledge of how effectively to steward the biodiversity and ecosystem services that influence them. Second, redesign requires farmers to work together, with collective action important across landscapes. Third, redesign requires institutional links between multiple stakeholders across scales. In essence, redesign is less about particular technologies or practices and more about the social, institutional, and human dimensions of learning, communicating, and monitoring dynamic agroecosystems.

Four broad principles characterize redesign initiatives:

1) A focus on transformation rather than management of an existing system. Redesigned farms are fundamentally altered by the addition of new elements, new configurations, and links between elements. There is an explicit emphasis on a new vision, and a commitment to tackle root causes. Redesign is achieved “when the causes of problems are recognized, and thereby prevented, being solved internally by site- and time-specific design and management approaches instead of by the application of external inputs” (Wright and Hill, 2011). Hill (2014) argues for a deeper

understanding of the psychosocial "roots" of unsustainable practice (within agriculture and in society more broadly) and distinguishes between "shallow" and "deep" orientations to change.

2) Redesign initiatives are founded on agroecological processes. Farmers actively steward farms and biodiversity to manage processes of predation, parasitism, allelopathy, herbivory, nitrogen fixation, pollination, and trophic dependencies (Gliessman and Rosemeyer, 2009; Gurr, 2016). While efficiency and substitution are based on particular inputs, practices, and technologies, redesign focuses on maintaining and managing biodiversity and whole ecosystems on and around farms. In doing so, the aim is to create "systems capable of sponsoring their own soil fertility, crop protection, and yield constancy" (Altieri, 2011).
3) Redesign involves new relationships and forms of organization, and is thus a social, political, and cultural challenge. It depends on social capital, which comprises relations of trust, reciprocity, common norms and sanctions, and connectedness (Pretty, 2020). Where these new relationships and forms of organization are nurtured, farmers can benefit from social learning, spread new ideas, share resources, and collaborate to advocate for their rights and entitlements.
4) Redesign is knowledge intensive and draws on a wider variety of knowledge-bases than is typical within conventional, high-throughput systems. This is supported by participatory and decentralized pedagogies. Farmer field schools, the use of new media, and multistakeholder platforms are all examples of tools that are being used extensively alongside scaled-up redesign initiatives. Nicholls (2018) highlights how peer-to-peer knowledge exchange has led to an "unprecedented return on agricultural technology investment."

3.2 Methods & study area

Our approach has been to compare CNF farm outcomes with local non-adopters (in the same village) across the state of Andhra Pradesh. We make these comparisons across all 13 districts (Study 1), and in three types of agroecosystems: high-input Godavari delta farm areas, low-input semi-arid farm areas, and tribal areas (Study 2). We have used two sources of data in the analysis: crop-cutting farm data from 2017–18 (Study 1: 1,828 farms, 34 villages), and rural survey data gathered in 2020–21 to assess the impacts of CNF adoption (Study 2: 562 farmers, 12 villages).

Study 1

Crop cuttings were taken in 2017–18 from two 5- x 5-metre samples in fields (10 x 10 metres for cotton), one from crops grown using CNF practices, and the comparison from conventional practices on the same farm or nearby (see Chapter 1 and 2 for more details). This control sample was taken either from a section of a CNF farmers' field where conventional practices were being used (most farmers stagger the adoption of CNF), or from an adjacent field where the same crop was being cultivated using conventional practices (subject to matching for soil type, seed variety, and irrigation regime).

Farms in all 13 districts of Andhra Pradesh were sampled. Some districts comprise mostly one type of existing high-input, low-input or tribal agroecosystem; others contain a mix. In the coastal districts of East Godavari, Srikakulam, Visakhapatnam, and Vizianagaram, both tribal and high-input areas exist. In general, East Godavari, West Godavari, Krishna, Guntur, Nellore, and Prakasam districts are

high-input areas. Anantapuramu, Chittoor, Kadapa, and Kurnool districts are relatively low-input semi-arid areas. All tribal agroecosystems are also low-input.

Study 2

The farm questionnaires were administered by RySS staff in the 12 villages in three districts, during the 2020–21 period of the pandemic and ensuing lockdowns (see details in Chapter 2).

Farms across these three zones have been subject to very different histories and cultures, resulting in differing trajectories of agricultural productivity and farm income, as well as external impacts on natural capital and ecosystem services:

1) Tribal zone, where CNF adoption is in comparison with traditional and indigenous practices largely untouched by modern agricultural development.
2) Semi-arid farming areas, where CNF adoption is made in comparison with farming practices that have remained low input over recent decades.
3) Godavari delta farming areas, where APCNF adoption is in comparison with farming systems that had adopted high use of pesticide, fertilizer, irrigation, and credit, and had hitherto achieved high yields.

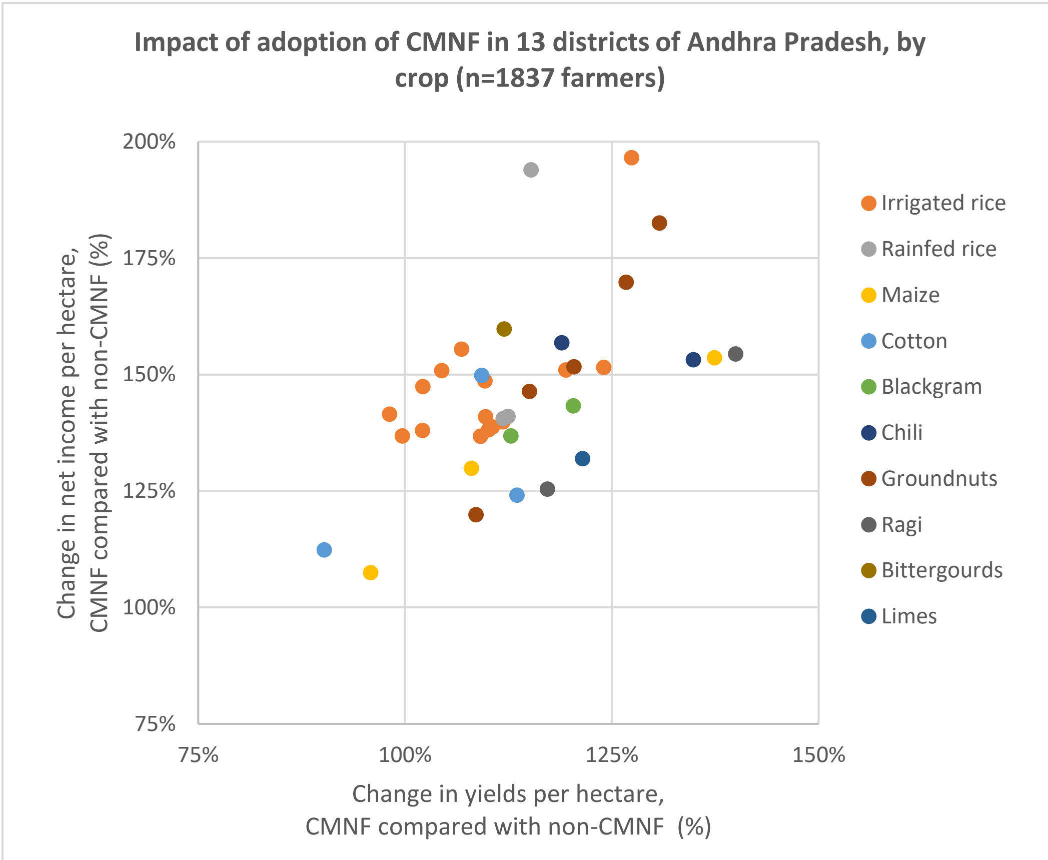
3.3 Crop yield & net income outcomes of CNF adoption (Study 1)

In the 13 districts sampled by 1,828 crop-cutting events in farmer fields, we have assessed the impacts of CNF on productivity for 9 crops: irrigated rice, rainfed rice, maize, cotton, groundnut, finger millet (ragi), chili, bitter gourd, and lime. In all cases, the improvements to productivity and net income with CNF were significant (at *, **, or *** levels; see Table 13). The average farm size for these CNF adopters was 0.98 ha.

With the adoption of CNF, the average yield increase ranges between 7.8 to 25.9%. This was accompanied by an increase in net income of 48.9%, indicating that farmers were benefitting from both increased yields and reduced costs of production. Yield increases were 8 to 12% for rice (irrigated and rainfed), maize, and cotton, and approximately twice this, 21 to 26%, for groundnut, finger millet (ragi), chili, bitter gourd, and lime (see Figures 3 and 4, and Table 13).

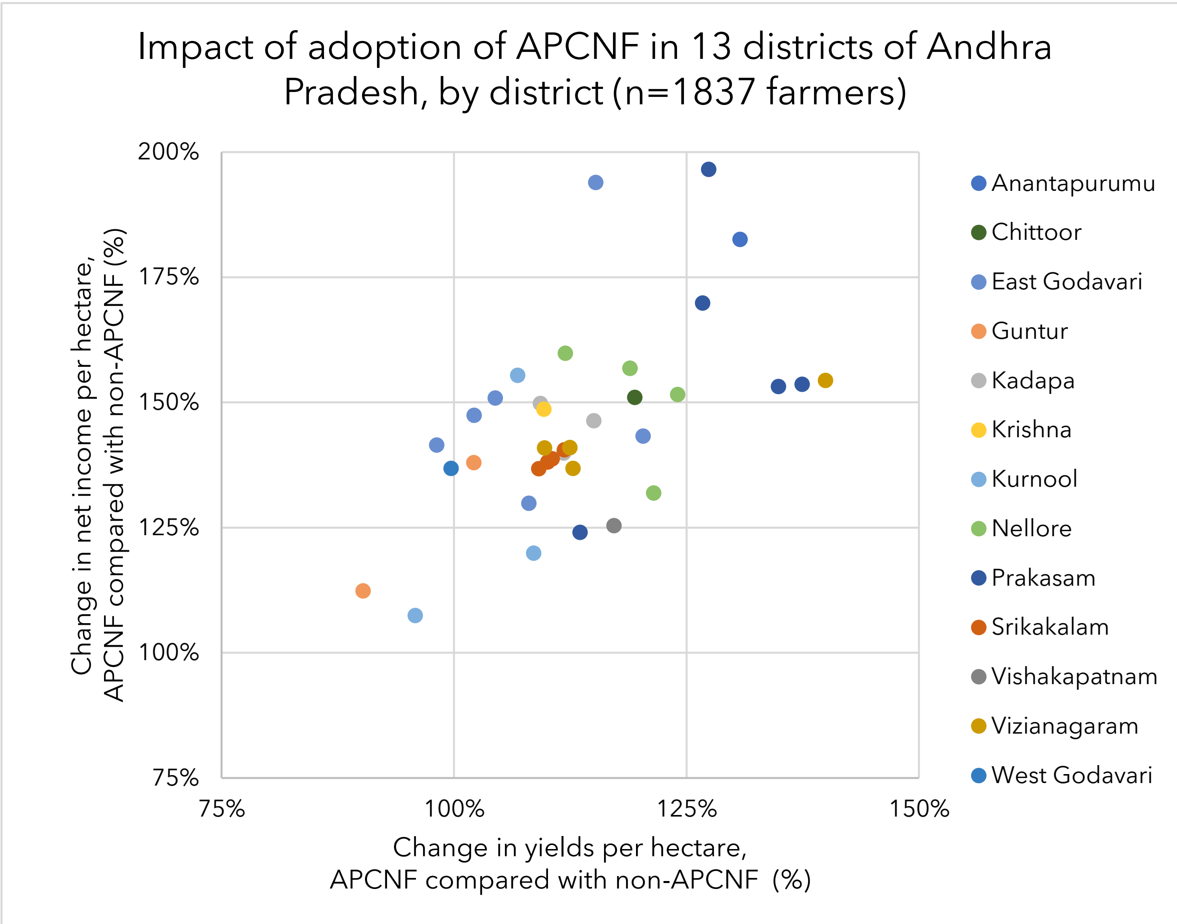
Net income increases were between +25% and +60%.

Figure 3: Impact of adoption of APCNF on yields & net income per ha



Source: Compiled by authors.

Figure 4: Impact of adoption of APCNF in 13 districts of Andhra Pradesh



Source: Compiled by authors.

Table 13: Impact of adoption of CNF on yields & net income in 13 districts

Crop	No. of farms sampled	Yield with CNF (t/ha)	% change in yield	Net income with CNF (USD/ha)	% change in net income
Rice, irrigated (paddy)	1,372	5.50***	+9.3%	803***	+49.0%
Rice, rainfed	205	5.55***	+12.4%	795***	+44.2%
Maize	14	6.19*	+7.8%	773*	+25.8%
Groundnut	154	2.57***	+25.1%	1,015***	+63.7%
Cotton	33	4.51***	+12.6%	3,239***	+25.1%
Finger millet (ragi)	23	1.66***	+23.5%	449***	+33.5%
Chili	13	6.83***	+25.9%	3,138***	+53.4%
Bitter gourd	6	10.5**	+21.1%	914**	+59.8%
Lime	8	16.9***	+21.1%	91,736***	+32.6%

Notes: t-test * = p<0.05; ** = p<0.01; *** = p<0.001

INR 1.00 = USD 0.013; 1.0 ha = 2.47 acres

a = aggregate crop yields and net income not calculated, as these are a mix of cereals, vegetables, and fruits

Average farm size for 1,837 farms = 0.98 ha.

Source: Compiled by authors.

We do not have sufficient data to draw conclusions on the impacts on yields and net income over time. It would be predicted that yields would improve as natural capital in the system improves (more ecosystem services contributing to the success of CNF) and as farmer knowledge and experience increases (more human capital) (Bharucha et al., 2020). Data from East Godavari District (100 farmers) showed that irrigated rice yields rose from -1.9% in year 1 (compared with conventional) to +4.4 in year two, with net income rising from +41% to +51%. In Srikakalam (180

farmers), irrigated rice yields rose from +9% in year 1 to +11% in year 2, with net income increasing from +37% to +39%.

3.4 Economic outcomes of CNF adoption (Study 2)

3.4.1 Descriptive statistics of the three agroecosystems

Across the 12 sampled villages in Vizianagaram (tribal), Anantapuramu (semi-arid), and West Godavari (Godavari delta), a total of 480 farm households were interviewed, representing 18.5% of all farmers in the 12 villages. The descriptive statistics of the sampled farms in terms of use of irrigation, land ownership, prior schooling, and access to support are set out in Table 14.

Table 14: Descriptive statistics on a sample of CNF & non-CNF farmers*

	Tribal area		**Semi-arid area**		**Godavari delta area**		**All farms**
	Without	**With CNF**	**Without**	**With CNF**	**Without**	**With CNF**	
Total households in villages sampled	227	141	428	541	713	537	2,587
Proportion of households sampled	21.1%	33.3%	27.1%	21.8%	16.3%	22.0%	22.0%
Average household size	4.3	5.4	4.3	4.4	3.6	3.7	4.1
Average farm size, owned and rented (ha)	1.94	1.81	1.63	0.95	2.13	1.23	1.56
Average age of farmer	45.9	43.4	49.7	45.6	48.6	45.3	46.9
Schooling							

None	40%	66%	40%	32%	30%	31%	36%
Primary	32%	6%	29%	22%	32%	34%	28%
Secondary	28%	23%	29%	43%	35%	30%	33%
Graduate	0%	4%	2%	3%	35	5%	3%
% of farm irrigated	39%	3%	39%	44%	97%	85%	63%
% of farm area under CNF	0	100%	0	91%	0	70%	
% of farms accessing agricultural capital	77%	36%	0	74%	0	70%	40%
% of farms receiving government support	44%	75%	0	75%	0	52%	36%
Labour use on farms							
Total hours per year	234	268	258	323	313	377	307
% labour by females	53%	51%	60%	50%	31%	42%	46%
% labour by males	47%	49%	40%	50%	69%	58%	54%

*Sampled: 480; total population n = 2587; CNF farms in shaded columns.

The average farm size was 1.5 ha, and the average age of the farmers was in the mid-40s across all three zones. It is noteworthy that for both low- and high-input areas, smallholder farmers have been early adopters of CNF. This indicates that farm size has not acted as an impediment to transitions to these forms of agroecological redesign. This is in keeping with evidence from elsewhere around the world, showing that smallholders can adopt various fundamental redesign initiatives and achieve significant environmental and economic gains (Pretty, 2018a).

Large numbers of farmers (64%) have not had any primary schooling. Again, the implication is that transitions to redesign systems, which are knowledge intensive, have not been impeded by a lack of formal education. Indeed, further engagement with knowledge-intensive CNF may have a positive social spill over effect, by increasing confidence in knowledge in farming and giving farmers access to new sources and modes of learning. Early adopters of CNF have had access to agricultural credit and government support. This has likely eased a transition to new modes of farming, and farmers may have been more ready to adopt CNF because of this. The wider implication is that to achieve scale, sustained policy support is likely important.

3.5 Impact on farm diversity

We now compare outcomes for CNF and non-CNF farmers within our sample. T-tests show statistically significant differences between CNF and non-CNF farmers in terms of farm diversity (see Table 15), with CNF farms more diverse, particularly in tribal and semi-arid regimes.

Adoption of CNF has resulted in an average increase in farm cultivation from 2.1 to 4 crops.

Table 15: Farm diversity with adoption of CNF

No. of crops grown on each farm	**Tribal area**	**Semi-arid area**	**Godavari delta area**	**All farms**
Without CNF	2.16	2.40	1.84	2.13
With adoption of CNF	4.51	4.88	2.92	4.00
Significance	***	***	***	***

Note: t-test * = p<0.05; ** = p<0.01; *** = p<0.001

3.6 Impact on on-farm labour use

Changes in on-farm labour use are summarized in Table 16. CNF farms tend to use more labour, with requirements rising from 277 to 336 hours per year; in particular, differences in labour requirements in low-input systems are highly significant.

Increased labour intensity is likely to be seen as a drawback by some farmers, particularly if the availability of household labour is low, but this could be viewed as an advantage at community and regional levels, allowing for increased employment in rural landscapes. Increased labour requirements (up 21% across all farms, from 277 hours to 336 hours) is significant in the sample. In some cases, this could pose a problem in the adoption of CNF, which will depend on farm labour availability and capacity to pay for local labour.

Table 16: Changes in farm labour with adoption of CNF

Labour use, family & hired (hours per year)	**Tribal area**	**Semi-arid area**	**Godavari delta area**	**All farms**
Without CNF	234	258	313	277
With adoption of CNF	268	322	377	336
Significance	No significant difference	**	No significant difference	*

Note: t-test * = p<0.05; ** = p<0.01; *** = p<0.001

3.7 Impact on costs for pesticide & fertilizer inputs

Savings are possible by cutting the use of inputs in the farm economy. CNF farmers have lower input costs, falling by 44% compared with non-CNF regimes. This saves CNF farmers USD 90 per farm (see Table 17), mainly as a result of shifts away from synthetic fertilizers and pesticides to locally produced CNF inputs such as seed, compost, and other formulations used widely in natural farming (described in Chapters 1 and 2).

There are important differences across production regimes: input costs for farmers in tribal and low-input systems do not change significantly as they shift to CNF. Differences become highly significant on high-input farms, with each CNF farmer saving an average of USD 212 per farm.

Table 17: Changes in costs of inputs per farm with adoption of CNF

Input costs (USD per farm)	**Tribal area**	**Semi-arid area**	**Godavari delta area**	**All farms**
Without CNF (using fertilizers and pesticides)	36	65	417	206
With adoption of CNF (organic & soil amendments)	43	56	205	116
Significance	No significant difference	No significant difference	**	*
Amount saved per farm on inputs (USD)	-$7.0	+$9.0	+$212.0	+$90.0

Note: t-test * = $p<0.05$; ** = $p<0.01$; *** = $p<0.001$.

These savings are predicted to result in important positive externalities (impacts on natural capital and ecosystem services) at both farm and landscape level, including reduced expenditure on healthcare and reduced water contamination from farm run-off (Sandhu, 2015; Pretty, 2018a). Pathogens, weeds, and invertebrates cause significant crop losses worldwide, and pesticide use in agriculture has grown steadily to 3.5 billion kilograms (kg) of active ingredient (a.i.) per year (Pretty, 2018a). Pesticides are, of course, intended to be hazardous to life, and there are risks associated with their use. The toxicity of pesticides can cause unintended harm on and beyond the farm (external costs). Additional private costs are borne by farmers themselves and tend not to be included in calculations of damage, such as the costs of personal ill health resulting from exposure to pesticides, or from increased pest, weed, or fungal resistance.

Andhra Pradesh has some of the highest rates of consumption of synthetic pesticides in India, with application rates of 0.87 kg a.i. per hectare (ha), against a national average of 0.3 kg per ha. In studies of pesticide externalities in China, Germany, Thailand, UK, and USA, external costs have been

calculated to range from USD 4 to 19 per kg a.i. (Leach and Mumford, 2008; Praneetvatakul, 2013; Norse, 2015; and Pretty, 2018a). These costs put annual pesticide externalities worldwide in the range of USD 10 to 60 billion (for the use of 3.5 billion kg and for a market size of USD 45 billion).

Using this data, we calculate that prior to adoption of CNF, the average farmed ha was producing USD 3.48 to 16.5 of economic damage to farm family health and natural capital. Thus a 44% reduction in the use of pesticides has created a benefit compared with existing practice (though technically this is a reduced cost). The pesticides not used on the 480 sampled farms amount to 354 kg a.i. annually, producing a local benefit of between USD 1,230 to 5,800 per crop season.

3.8 Impact on income from four sub-components of farm systems

We now turn to shifts in income across the totals from four production sub-systems: 1) kharif crops, 2) rabi crops, 3) livestock, and 4) perennials, focusing on gross income (before costs) and net income, and by farm unit and area (ha/ha) (see Table 18).

There was a significant increase, more than a doubling, in gross income in the semi-arid area, but no significant difference for tribal farmers. Farmers in high-input systems of the Godavari delta experienced significant falls in gross income, appearing to make CNF a more difficult proposition in these regimes. However, gross income per ha increases significantly by USD 684 (+28.3%) overall with the adoption of CNF across three regions. It increases significantly in the high-input farming in the Krishna-Godavari delta region by USD 1,728 per ha (+42.3%).

Following this, net income is also significantly higher on low-input CNF farms (semi-arid areas), by some USD 830 per farm. However, high-input CNF farmers in the Godavari delta area have a lower net income compared with non-CNF farmers.

Net income per ha doubles with the adoption of CNF by USD 1,177 (+99.1%) across three regions. The highest increase per ha is recorded in the high-input farming in the Krishna-Godavari delta region by USD 2,401 (+104.5%), followed by the semi-arid southwestern region by USD 404 (+88%).

Table 18: Changes in farm income (gross and net) per farm & ha with the adoption of CNF, totals for all four sub-systems (kharif & rabi crops, livestock, perennials)

Gross income (USD per farm) across kharif & rabi crops + livestock + perennials	**Tribal area**	**Semi-arid area**	**Delta area**	**All farms**
Without CNF	527	791	4,873	2,448
With adoption of CNF	545	1,635	2,804	1,938
% change	+3.4%	+106.7%	-42.4%	-20.8%
Significance	No significant difference	***	***	**
Net income (USD per farm) across kharif and rabi crops + livestock + perennials	**Tribal area**	**Semi-arid area**	**Delta area**	**All farms**
Without CNF	275	131	2,637	1,193
With adoption of CNF	340	963	2,173	1,364
% change	+23.6%	+635%	-17.6%	+14.3%
Significance	No significant difference	***	**	***
Gross income per ha (USD) across kharif and rabi crops + livestock + perennials	**Tribal area**	**Semi-arid area**	**Delta area**	**All farms**

Without CNF	414	1,448	4,087	2,413
With adoption of CNF	503	1,529	5,816	3,097
% change	+21.5%	+5.5%	+42.3%	+28.3%
Significance	No significant difference	No significant difference	**	**
Net income per ha (USD) across kharif and rabi crops + livestock + perennials	**Tribal area**	**Semi-arid area**	**Delta area**	**All farms**
Without CNF	269	459	2,297	1,187
With adoption of CNF	276	863	4,698	2,364
% change	+2.6%	+88.0%	+104.5%	+99.1%
Significance	No significant difference	*	***	**

Notes: t-test * = $p<0.05$; ** = $p<0.01$; *** = $p<0.001$

INR 1.00 = USD 0.013; 1.0 ha = 2.47 acres

3.9 Impact on farm financial indicators

Further financial data from farms – including farm costs, income, household savings, and expenditure on labour, seeds, and machinery (see Table 19) – show positive results. Farm costs fell on 77% of farms, most markedly on farms in the semi-arid area, where 87% of CNF farmers reported improvements; similarly, farm income improved on 67% of farms.

Expenditure on labour, seeds, and machinery also improved on a significant percentage of households. Expenditure on labour fell on 35% of farms, and expenditure on seeds and machinery fell on just over half (51%) of farms. At household level, 60% of farmers reported improved household savings; amongst tribal farmers, 68% reported improvements in household savings.

Table 19: Changes in farm financial indicators with adoption of CNF

	Tribal area	Semi-arid area	Godavari delta area	All farms
Farm costs: Improved	77%	87%	70%	77%
Farm costs: Worsened	6%	4%	18%	11%
Farm income: Improved	70%	62%	72%	67%
Farm income: Worsened	2%	2%	3%	2%
Household savings: Improved	68%	54%	63%	60%
Household savings: Worsened	0%	1%	4%	2%
Labour use on farm: Improved (reduced)	49%	33%	32%	35%
Labour use on farm: Worsened (increased)	30%	14%	20%	19%

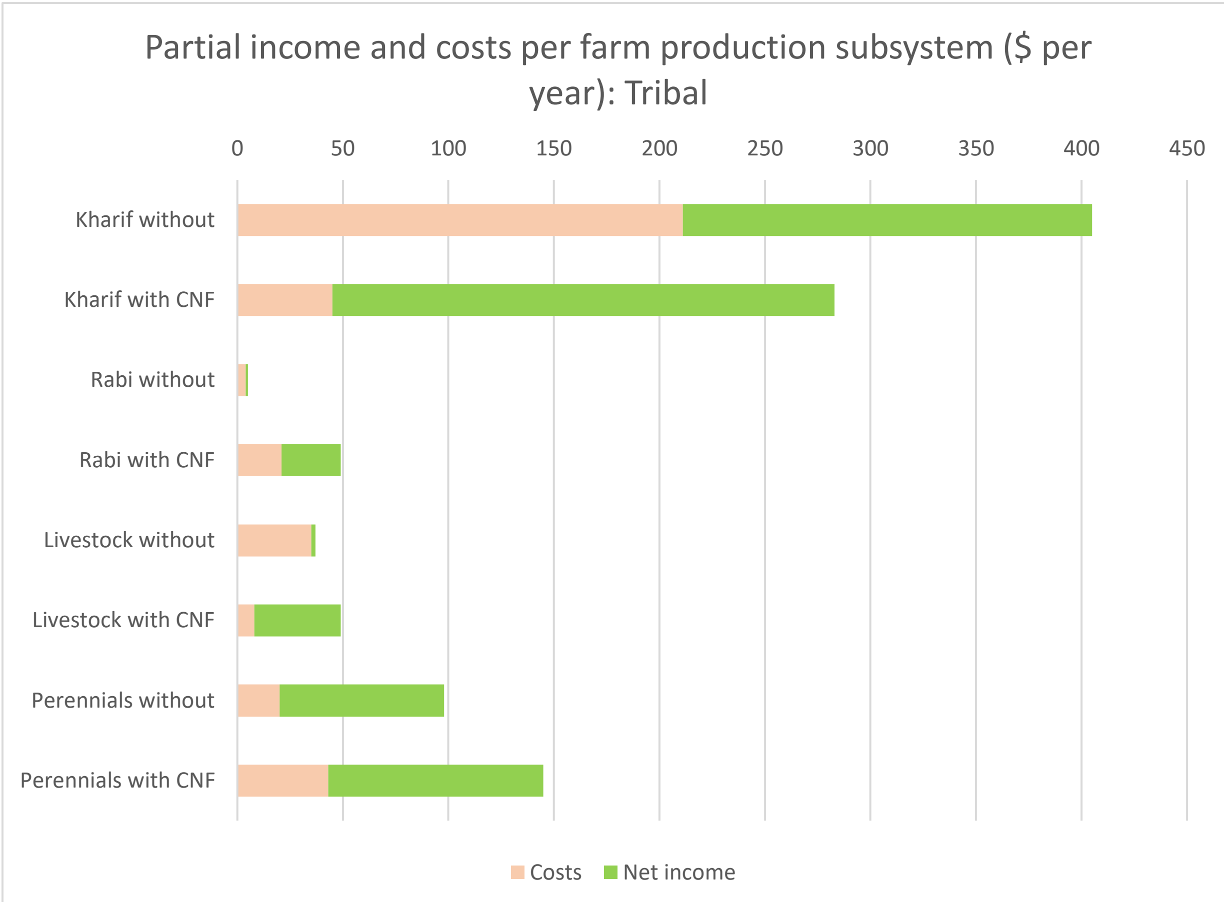
Expenditure on seeds & machinery: **Improved (reduced)**	68%	44%	51%	51%
Expenditure on seeds & machinery: **Worsened (increased)**	9%	15%	17%	15%

The farm survey also allowed us to assess partial changes to income and costs by production regime and across kharif crops, rabi crops, livestock, and perennials (see Figures 5 to 8). These show important changes in costs and income. The graphs are stacked: pink represents costs within the total income; green represents net income.

In some cases, CNF reduces income (e.g., in Godavari delta kharif); in other cases, CNF increases income (e.g., in semi-arid kharif and in tribal perennials). Livestock and perennial sub-systems are clearly very important to farmers. The overwhelming majority of farmers reported improvements in farm costs after the adoption of CNF. Amongst farmers in the semi-arid area, 87% reported improvements and only 4% reported a worsening. Similarly, most farmers across all production systems reported improvements to farm incomes. Household savings, too, were reported to have improved across all farm categories.

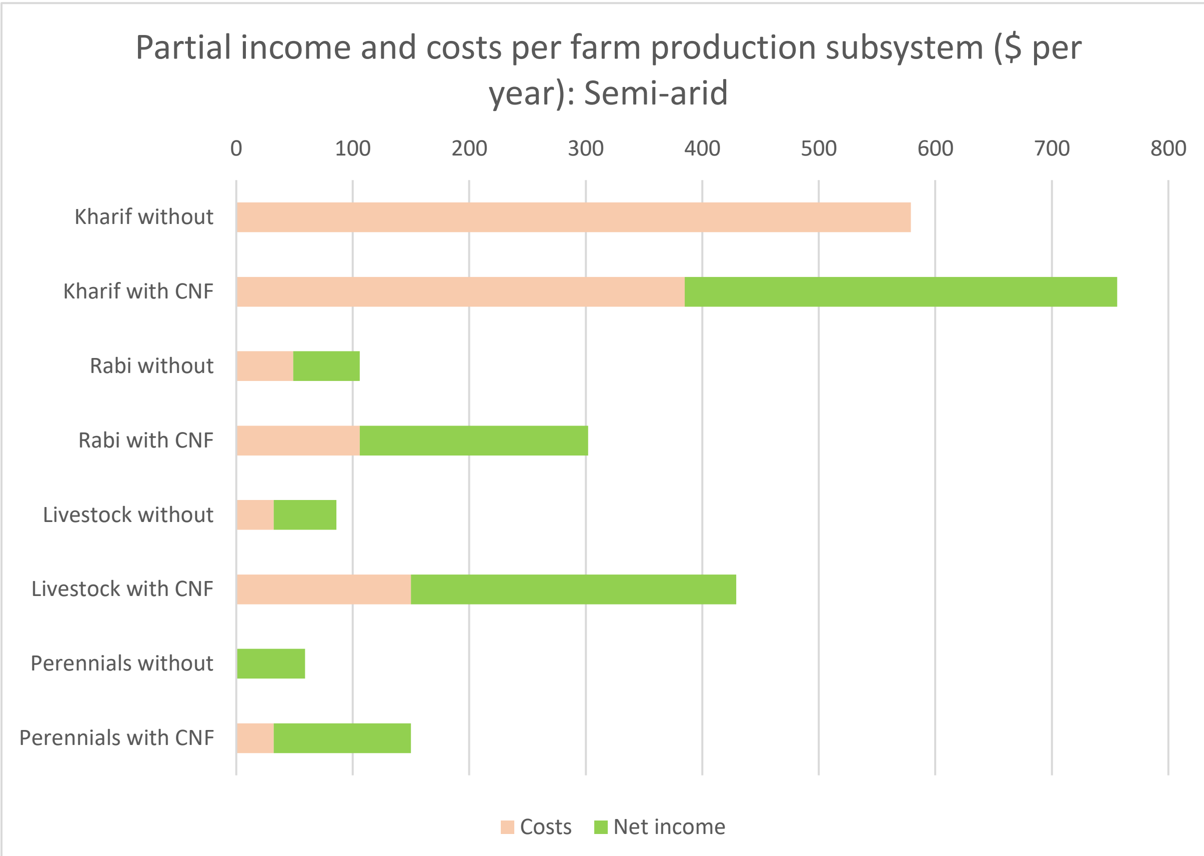
The picture is slightly more mixed when it comes to changes in labour use and expenditure on farms, indicating that for some farmers (across all farm categories) adoption of CNF has required greater investment in labour and in farm operations. This, however, is offset by increased incomes and better farm performance, so taken alone should not be considered a barrier to adoption.

Figure 5: Partial income & costs per farm production subsystem (USD per year): Tribal



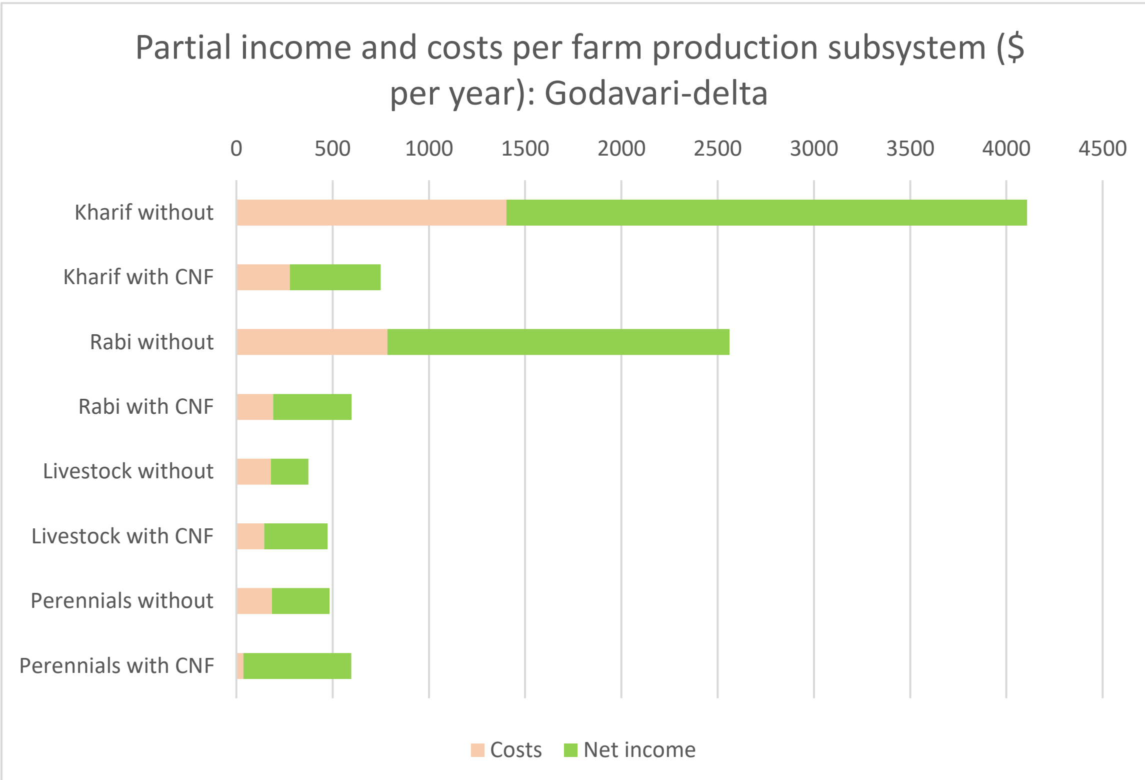
Source: Compiled by authors.

Figure 6: Partial income & costs per farm production subsystem (USD per year): Semi-arid area



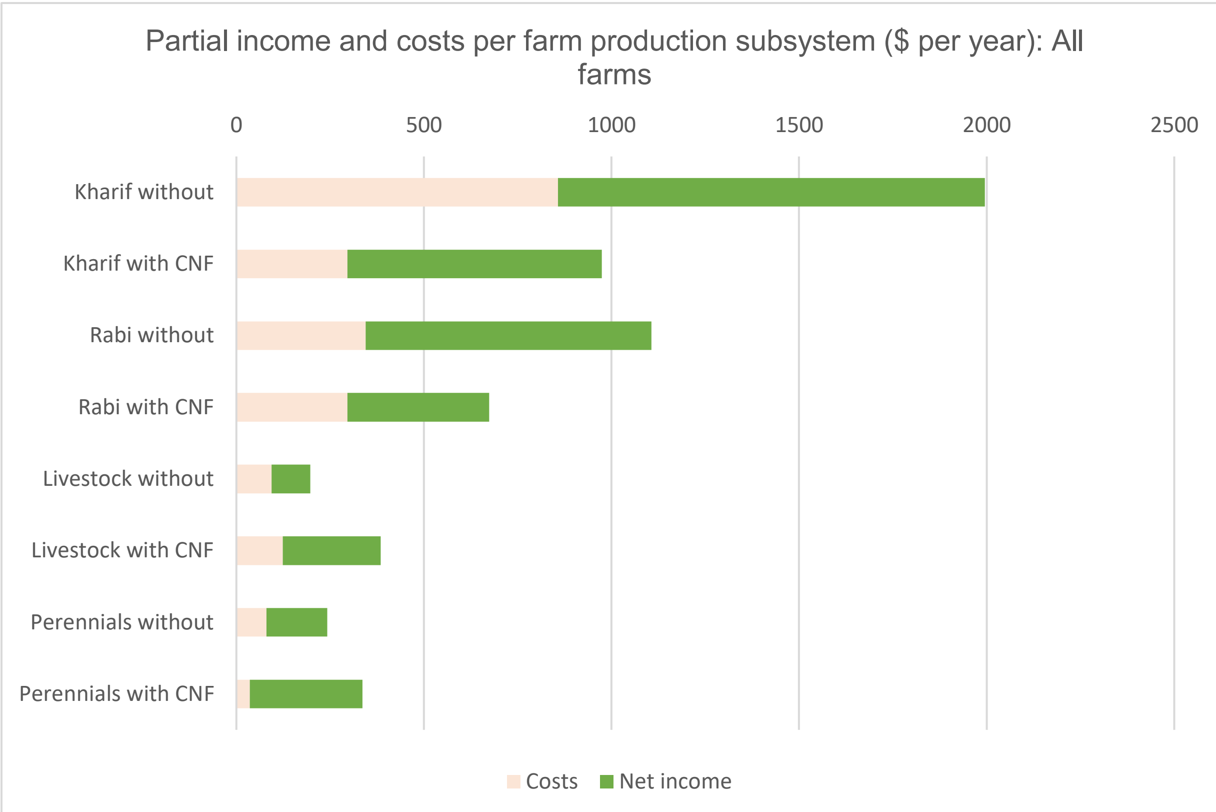
Source: Compiled by authors.

Figure 7: Partial income & costs per farm production subsystem (USD per year): Godavari-delta area



Source: Compiled by authors.

Figure 8: Partial income & costs per farm production subsystem (USD per year): All farms



Source: Compiled by authors.

3.10 Overview

The adoption of CNF systems across all 12 districts and in the 3 agroecosystems (tribal, semi-arid, Godavari delta area) has had positive impacts on farm productivity, gross and net income, labour requirements, and input-use. Table 20: Summary of changes with adoption of CNF in three districts of Andhra Pradesh summarizes the headline changes as a result of farmers' adopting CNF. Gross and net income falls *per farm* in the Godavari delta region with CNF. On the contrary, net income per farm increases on average over all farms.

More importantly, at the *per ha* level, both gross and net income increase in the Godavari delta region, as well as in the other agroclimatic regions, too (because costs fall considerably).

Table 20: Summary of changes with adoption of CNF in three districts of Andhra Pradesh

	Tribal area	**Semi-arid area**	**Godavari delta area**	**All farms**
Crop diversity on farms	Up 108%	Up 103%	Up 59%	Up 88%
Labour use per year	Up 15%	Up 25%	Up 20%	Up 20%
Changes in input costs from fertilizer and pesticides to CNF inputs	Up 15%	Up 16%	Down 103%	Down 76%
USD saved per farm from input-use changes	Loss of $7 per farm	Up $9 per farm	Up $212 per farm	Up $90 per farm
Net income (USD) per ha	Up $7 per ha	Up $88 per ha	Up $580 per ha	Up $421 per ha

% farmers with improved costs	77%	87%	70%	77%
% farmers with improved income	70%	62%	72%	67%
% farmers with increased household savings	68%	54%	63%	60%
% farmers with reduced labour requirements	49%	33%	32%	35%
% farmers with reduced expenditure on seeds and machinery	68%	44%	56%	51%

Source: Compiled by authors.

CNF farmers have begun a process of system redesign. Such agricultural system redesign poses not only social, cultural, and institutional challenges but also technological and procedural learning curves (Hill, 1985; Hill and McRae 1996). Farmers adopting CNF have adapted methods to suit the practicalities of their individual farms, setting out a suite of approaches and farm designs (Khadse, 2017). Methods may also change year by year, depending on external drivers (e.g., weather patterns, crop prices) or imperatives at farm and household levels. Farmers adopting CNF in Andhra Pradesh through structured support from RySS also tend to adopt methods progressively (Khadse, 2019), leading to a broad range of farm agroecosystems across a landscape.

In July 2018, a two-day exercise was conducted with CNF farmers, who were asked to follow a single instruction: to graphically illustrate significant changes to their farms, households, or wider communities since the uptake of ZBNF (Bharucha and Pretty, 2020). Farmers were left to show what they felt were the most important changes. Descriptions were captured through drawings, with the support and facilitation of local Natural Farming Fellows. The illustrations obtained consisted of resource maps of local villages and fields; social maps showing new webs of relationships supporting crop cultivation, harvesting, storage, and sale; food plates reflecting new dietary regimes; as well as graphs charting income, expenditure cycles, and value chains. Figure 9 provides an example, and key themes are summarized in Table 21. Further work is necessary to assess how these various outcomes play out over time and across a stratified sample of ZBNF farms.

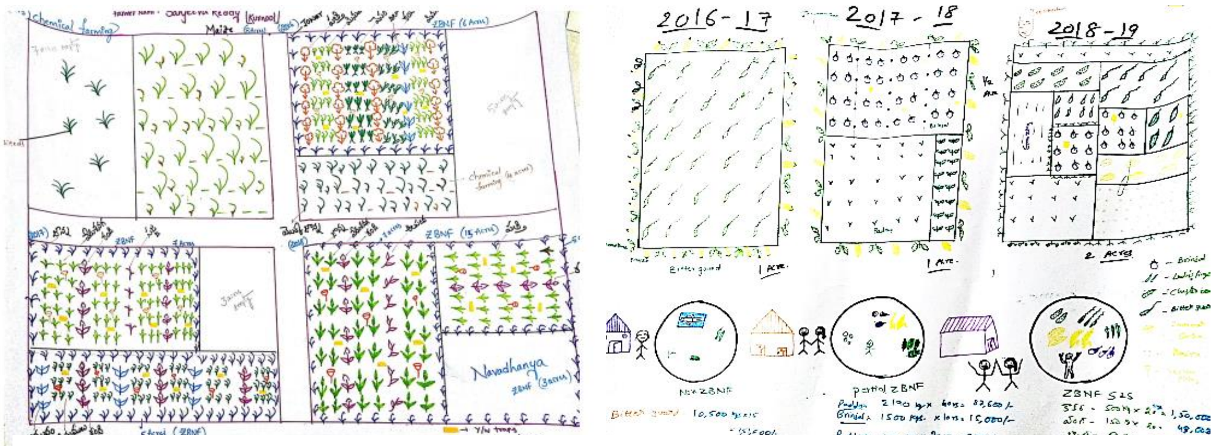


Figure 9: Resource (field) map representations on the evolution of cropping systems on a rainfed farm, Kurnool District

Source: Compiled by authors.

Table 21: Key themes from farmers' testimonies on CNF outcomes for farms & households

Theme	Comments
Crop health & resilience	Farmers reported greater crop resilience to dry spells and other climate shocks. Income figures showed that losses of some high-value crops due to pest attacks or climate shocks were adequately offset by stable yields in other crop types, an outcome enabled by the RySS model of encouraging more complex crop mixes. Incomes were good, due to significantly lower production costs.
Greater crop diversity & more complex cropping patterns	Farmers illustrated transitions from monocropping to polycropping, with the year-on-year addition of new crops and crop mixes, the design of new rotations, and more complex cropping patterns. One farmer illustrated a transition from 1 crop type in 2016 to 10 in 2018, representing increases not only in diversity and productivity, but also in human and natural capital.
Food plates	Farmers illustrating food plates drew a greater number of food types as well as greater quantities of food.
Health	Farmers illustrated a transition from periods of ill health to better health; smiling faces illustrated positive effects.
Incomes	Farmers illustrated improvements to housing, with transitions from *katcha* (rough, thatched) housing to *pukka* (permanent, concrete or mortar) housing.

Source: Compiled by authors.

3.11 Conclusions & next steps

The Rythu Sadhikara Samstha (RySS) in Andhra Pradesh (RySS, 2018) has positioned itself as an organization that seeks to drive transformative benefits for the economy, environment, and equity through sustainable agriculture. Its aims are to: "Convert the agriculture sector of Andhra Pradesh to 100% regenerative agriculture; community managed natural farming through 6 million smallholders will deliver transformative benefits for the economy, environment, and equity. It will present a first-of-its-kind blueprint for sustainable commodities production that reverses biodiversity losses and preserves ecosystem services, providing an opportunity for reclaiming planetary boundaries."

We have seen that CNF increases crop yields, reduces costs of production (low fertilizer and pesticide input-use, lower costs of seeds and machinery), and thus increases net income per ha. CNF also increases diversity on farms (number of crops) and increases demand for rural labour. There are additional benefits from reduced negative impacts of pesticide use.

A key component of the sustained scaling of CNF in Andhra Pradesh has been the layering of initiatives and diversity of adoption pathways, allowing for the experience to build. The RySS acts as the core agency responsible for all aspects of the roll-out of CNF, and its work is supported by funding from the central and state government and private philanthropy (Aziz Premji Foundation). This offers the opportunity to create substantial benefits for farmers, people living in rural areas, and the economy of Andhra Pradesh.

We suggest two priorities to support the pace and quality of adoption of CNF. First, there is a need for more time series data. Improvements in natural, human, and social capital are expected to lead to growing productivity and positive economic change. At the same time, redesign initiatives are not static, as ecological and economic contexts continually change. Multidisciplinary longitudinal assessments would explore how practice and outcomes change over time, either progressing toward greater sustainability or reverting to older forms of management. Unintended consequences may also unfold, and it will be important to understand these before they come to limit the success of CNF (Pretty, 2018b).

Second, CNF is founded on the importance of farmer-led and -focussed knowledge exchange. While RySS staff teach the formalized component of CNF to farmers, it is clear that RySS aims to give farmers scope to experiment with methods, adapt them, and adopt CNF progressively. This involves both techniques and principles (Khadse and Rosset, 2019). RySS has created a participatory learning ecosystem to facilitate collective learning through face-to-face interaction with peers and other experts, through exposure to video and other media, and through direct engagement with training camps (Walker et al., 2021). At the same time, farmers have revealed that it is not possible to start with high-complexity concepts in the first year (Khadse and Rosset, 2019, p. 15). Farmers tend to begin by using CNF as a form of input substitution before moving on to more advanced practices and engaging with the underlying principles.

Andhra Pradesh's success with CNF has enthused policy makers in other states as well as at the national level. It will be important for farmer-focused programs to be replicated, as well as the

technologies and methods, enabling farmers elsewhere to create rich learning ecosystems, supported by peers and more conventional experts. In Sikkim, farmers who transitioned to organic approaches (and thus away from synthetic inputs) were not provided with sufficient guidance on how to deal with crop pests (Das and Bhattacharyya, 2018). Nonetheless, the clear evidence from the adoption of CNF indicates that increased adoption in Andhra Pradesh and elsewhere should bring further economic and agricultural benefits.

4 Valuing the social capital in Andhra Pradesh CNF

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Take-home messages

1) CNF increases social capital, which improves the capacity to adapt to stressors, increases household food security, and allows knowledge to be exchanged through networks.
2) Three dimensions of social capital are measured: structural, cognitive, and relational social capital.
3) The study confirms that social capital has positive productivity gains for farmers and that women play a crucial role in facilitating community farming.
4) The comprehensive social capital index is significantly higher in villages practising CNF than in non-CNF villages. Of the various dimensions of the social capital, information provision, collective action, and perception to risk significantly influence productivity.

4.1 Social capital & its role in CNF

CNF is a sustainable production alternative to high externality–generating conventional farming (TEEB, 2018; RySS, 2021; Pretty, 2006). The success of CNF relies on many factors, significant among which is the extent of networking and cooperation among and across farming households, the farming community, their consumers, and their more prominent stakeholders (Saint Ville et al., 2016). Thus, along with the environmental, economic, health, and social benefits of organic and natural farming worldwide, such activities generate valuable social capital among the farming community.

Social capital can be defined, interpreted, and measured in multiple ways and conceptualized using multiple dimensions (Putnam, 1993b; Narayan and Pritchett, 1999; Onyx and Bullen, 2000; Grootaert et al., 2003; Rupasingha, Goetz, and Freshwater, 2006; and Sabatini, 2009). The literature has taken several different views on social capital. Bourdieu (2000) views social capital as individuals' access to networks. Coleman (1988) views it as a variety of entities. These two views relate social capital to resources that individuals can procure due to their relationship with others (Burt, 2000). Putnam (1993b) considers social capital as the association between people that facilitates cooperation and coordination, thereby improving their welfare. Most of the developed literature considered social capital as multivariate and multidimensional. Each dimension exerts beneficial effects on economic performance. Another definition of social capital is the "productive value of the social connections that enhance social well-being" (Stevens and Smith, 2013). Summarizing various approaches, Stevens and Smith (2013) give four different interpretations of social capital based on individual, private activities and outcomes, collective activities and outcomes, the structure of the networks that maintain them, and the different types of resources and outcomes generated by the networks. Here, we adopt the TEEBAgriFood definition of social capital, which identifies social capital as "networks with shared norms, values, and understandings that facilitate cooperation within or among groups" (Cote and Healy, 2001).

Agricultural communities face numerous economic, social, and environmental challenges, so farmers have evolved various coping strategies to deal with these challenges. A number of these strategies depend on the availability and use of social capital. Numerous studies have illustrated the central role played by social capital in catalyzing peer-to-peer learning, innovation, adoption of sustainable agriculture practices, and motivating greater participation in resource governance or conservation programs in individual farming communities (Bandiera and Rasul, 2006; Lubell, Henry, and McCoy, 2014; Saint Ville, Hickey, and Phillip, 2017; and Munasib and Jordan, 2015).

Social capital improves the capacity to adapt to stressors and increases household food security in times of hardships (Niles and Salerno, 2018). It allows knowledge to be exchanged through networks (Slijper et al., 2022), and enhances household food security outcomes among smallholder farms in low-income countries (Niles et al., 2021).

Various indicators have been used in the literature to measure the extent and condition of social capital. These indicators include collective action and cooperation, adherence to norms and regulations, participation in local organizations and groups, and social cohesion and inclusion (Grootaert, 2002). The TEEBAgriFood Evaluation Framework acknowledges that social capital may be reflected in formal and informal arrangements, and can be considered the “glue” that binds individuals in communities. The following section outlines how our study scopes and frames the development of social capital and outlines our approach for its measurement and evaluation by designing and using an appropriate set of indicators.

4.1.1 Scope of this chapter

The objectives of the social capital evaluation in this study are to:

1) Analytically quantify the social capital using a comprehensive multi-dimensional index among adopters and non-adopters of community natural farming villages at the farmer household level. The estimates provided a baseline against which the social capital under APCNF is monitored.
2) Check whether the adoption of natural community farming improved the social capital of the villagers.
3) Examine the extent to which the social capital helped improve the productivity of the farms.
4) Assess the role played by women in the adoption of natural community farming.

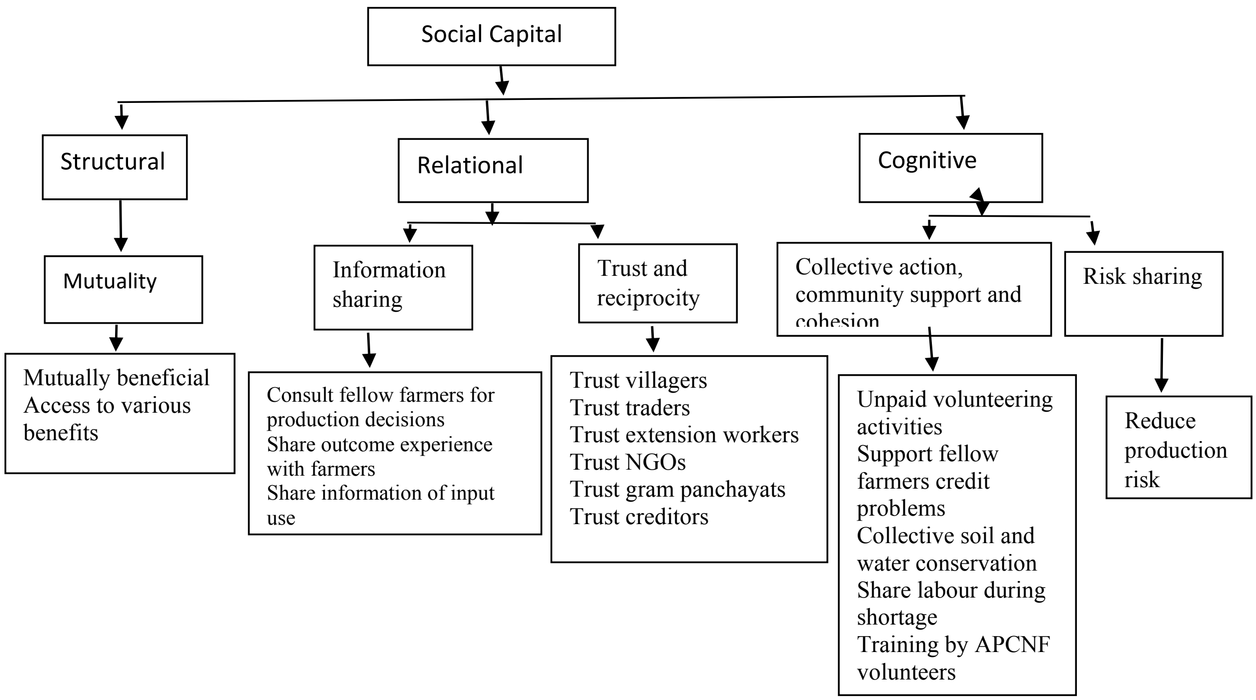
4.2 Framework & data sources for measuring social capital

Different dimensions and sub-dimensions of social capital are measured through various indicators relevant to the local context. The data for this study is based on a large primary survey carried out during 2020–2022 in East Godavari, Vizianagaram, and the Anantapur districts of Andhra Pradesh, where CNF is actively practised. The survey details have been discussed earlier in the report and include an extensive set of variables representing different dimensions and sub-dimensions capturing social capital and a large set of control variables related to individual sociodemographic and socioeconomic characteristics. The study relies on principal components and regression analysis to achieve the listed objectives.

Based on the different relevant dimensions considered by various studies, three dimensions of social capital are considered relevant for constructing comprehensive social capital indicator in the context of CNF: structural, cognitive, and relational social capital. The structural form of social capital refers to the interpersonal formation of links between individuals or groups (Gomez-Limon, Vera-Toscano, and Garrido-Fernandez, 2013) and how they mutually benefit from interactions with homogeneous groups (bonding), heterogeneous groups (bridging), and through various ties (linking) (see Putnam, 2000). The relational dimension is based on the type of personal relations people build between them, and some of the indicators include trust and trustworthiness (Fukuyama, 1995; Putnam, 1993a), norms and social sanctions (Coleman, 1990; Putnam, 1995), and reciprocity (Coleman, 1990). The cognitive dimension refers to a shared paradigm that facilitates achieving collective goals and shows how compatible the individuals are with community values (Putnam, 2000). These multiple dimensions can be captured through various indicators that consider social capital to facilitate individual cooperation and coordination. Building one composite aggregate indicator from these various indicators is complex. However, it is considered valuable to understand how community farming helped build social capital in the region and contributed to environmental sustainability.

Figure 10 gives the Framework adopted for analysis in the study and the three sub-dimensions and their respective indicators. Multiple indicators have been considered, but the indicators listed in the figure have emerged as key indicators in the study areas. The dimensions and sub-dimensions have been adopted from various base indicators (Poli, 2015) for the District of Wardha. Table 22 gives the descriptive statistics of the key indicators under each of the dimensions considered in the study.

Figure 10: Dimensions, sub-dimensions, & indicators used in the study



Source: Author's analysis.

Table 22: Description of the dimensions, sub-dimensions, & indicators used in the study

Dimension	Indicator	Description	Ranking
Mutuality	MB1	Mutual benefit perception rating by being part of a farmers' group	Extremely beneficial = 5, Very beneficial, Moderately beneficial, Somewhat beneficial, Not beneficial = 1
	MB2	Beneficial in obtaining credit	Yes = 1, No = 0
	MB3	Better access to agricultural inputs	Yes = 1, No = 0
	MB4	Benefit from sharing labour	Yes = 1, No = 0
	MB5	Access to shared irrigation	Yes = 1, No = 0
	MB6	Benefit from access to markets	Yes = 1, No = 0
	MB7	Other benefits	Yes =1, No = 0
Reciprocity	R1	Knowledge on whom to consult for information	Always = 5, Many times, Sometimes, Rarely, Never = 1
	R2	Sharing information on new varieties and methods	Always = 5, Many times, Sometimes, Rarely, Never = 1
	R3	Share outcome experiences with other farmers	Always = 5, Many times, Sometimes, Rarely, Never = 1
	R4	Support fellow farmers' credit problems	Always = 5, Many times, Sometimes, Rarely, Never = 1
Trust	T1	Level of trust on villagers for support	Very good = 5, Good faith, Fair, Somewhat trustworthy, Not at all trustworthy = 1
	T2	Level of trust on traders whom farmers sell produce to	Very good = 5, Good faith, Fair, Somewhat trustworthy, Not at all trustworthy = 1
	T3	Trust agricultural extension services	Very good = 5, Good faith, Fair, Somewhat trustworthy, Not at all trustworthy = 1
	T4	Trust Gram Panchayat that they work for village interest	Very good = 5, Good faith, Fair, Somewhat trustworthy, Not at all trustworthy = 1
	T5	Trust each other for lending and borrowing	Very good = 5, Good faith, Fair, Somewhat trustworthy, Not at all trustworthy = 1
Information support	IS1	CNF volunteers provide technical support	Always = 5, Many times, Sometimes, Rarely, Never support = 1
	IS2	Community representatives provide information	Always = 5, Many times, Sometimes, Rarely, Never support = 1

Collective action	CA1	Implement soil and water conservation collectively	Always = 5, Mostly collectively, Mostly individually, Only individually, Never implemented = 1
Community cohesion	CS1	Sell produce collectively	Always = 5, Mostly collectively, Mostly individually, Only individually, Never implemented = 1
	CS2	Consult fellow farmers for decisions	Always = 5, Many times, Sometimes, Rarely, Never = 1
	CS3	Help unpaid volunteering activities	Always = 5, Many times, Sometimes, Rarely, Never = 1
	CS4	Share labour during the shortage	Always = 5, Frequently, Sometimes, Rarely, Never = 1
Risk reduction	RR1	Perception of farmers' cooperative risk reduction	Always, Many times, Sometimes, Rarely, Does not reduce risk = 1
	RR2	Local NGOs support benefitting the villages	Very good = 5, Good, Fair, Somewhat, Not at all = 1

4.3 Methodology for constructing a comprehensive multidimensional index using Principal Component Analysis

This section discusses the procedure employed to create a composite social capital index (Objective 1). A comprehensive social capital index has been created using the indicators listed in Figure 10 and Table 22, and the various dimensions have been assigned a certain weight. The weights should ideally come from expert opinion. However, given the limited capacity of the experts to weigh different indicators, we used a Principal Component Analysis (PCA) approach (see OECD-JRC, 2008). The main objective of the PCA is to explain the variance in the dataset through an array of the orthogonal (uncorrelated) linear combination of original variables called principal components (PCs). In simpler terms, finding the PC is equivalent to find the dimensions, or, equivalently, the parameters, that better describe the data. The PCA is briefly discussed in Appendix 1.

4.4 Results of the composite social capital index in CNF & Non-CNF villages (Objective 1)

Six sub-dimensions had an eigen value greater than 1 (see Table 23 for the factor loadings from PCA):

1) *Information sharing* refers to information shared with farmers by CNF volunteers.
2) *Mutuality* refers to perceptions around mutual benefits and access to those benefits via a shared network.
3) *Collective action* refers to actions whose implementation affects all the social actors involved.

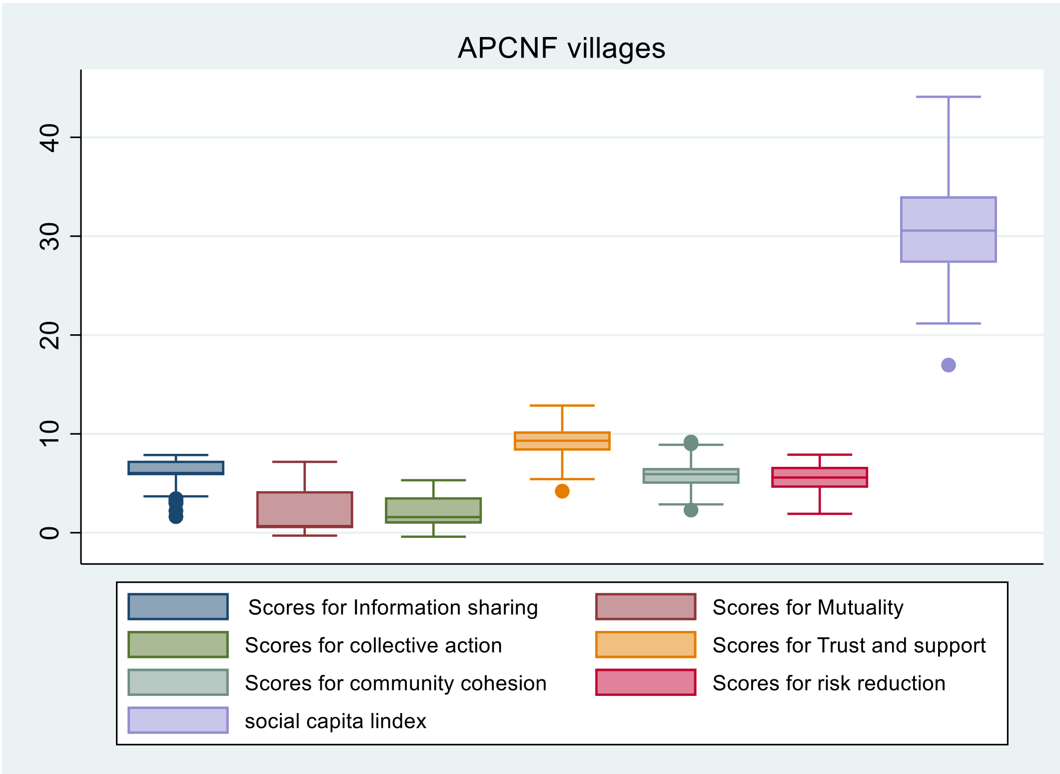
4) *Trust and trustworthiness* refer to the level of trust imposed on villagers, traders, extension workers, gram panchayats, lenders, and borrowers.
5) *Community support and cohesion* refers to farmers' volunteer work on each farm, sharing labour in case of shortages, and consulting fellow farmers regarding production decisions.
6) *Risk reduction* refers to the perception of risk reduction by being part of the network and the support extended by NGOs regarding the same – the indicators of collective soil and water conservation map well under community action.

The PCA results indicate considerable differences between CNF and non-CNF villages across various components of social capital, as shown in Table 23 and Figures 11 and 12. Figures 11 and 12 give the box plot of various sub-components of social capital considered in the study.

Figures 11 and 12 show that trust and support have the highest incidence frequency among the distribution of different social capital scores (in CNF villages, trust and support have the highest incidence frequency, while the score for collective action has the lowest score). Some effort is needed to enable collective action. In non-CNF villages, the data suggests there is little information sharing or mutual sharing of benefits (the scores are very low). In the category of collective action, there is no significant perceptible difference between CNF villages and non-CNF villages; however, differences are shown in other components.

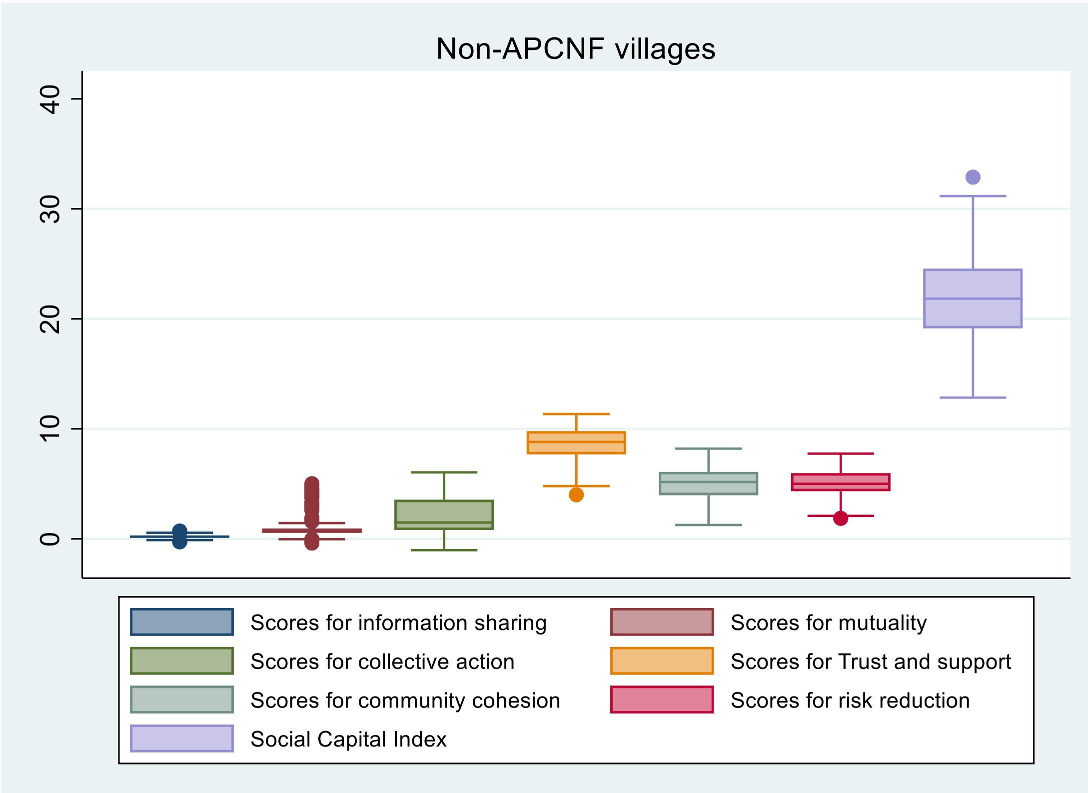
Table 23 (the factor loadings matrix) shows that among the components of social capital, the scores for trust and support, community cohesion, and risk reduction rank high, in descending order. Table 24 shows the significant differences between CNF villages and non-CNF villages when it comes to social capital formation. (A mean test is used to check whether the differences are significant, and the results show that except for the component of collective action, there is a significant difference in various components of social capital.) The aggregate social capital indicator is high in the villages where CNF is active. Table 25 gives the village-level components of social capital (the villages where CNF is active are highlighted).

Figure 11: Box plot showing various components of social capital in CNF villages



Source: Estimated by author.

Figure 12: Box plot showing various components of social capital in non-CNF villages



Source: Estimated by author.

Table 23: Rotated components matrix from PCA (factor loadings)

Components Indicators	Information support	Mutuality	Collective action	Trust & reciprocity	Community support & cohesion	Risk reduction
Mutual benefit perception	0.024	0.857	0.015	0.006	-0.038	-0.035
Access to benefits	-0.119	0.466	0.040	-0.059	0.058	0.049
Reduce production risk	0.002	0.056	-0.245	-0.031	0.078	0.634
Share information new varieties	0.033	0.056	0.007	0.292	0.098	0.064
Share outcome experience with farmers	0.032	0.026	0.032	0.326	0.097	0.031
Consult fellow farmers regarding production	-0.021	-0.080	0.197	0.128	0.310	-0.067
CRPs provide information	0.700	0.007	0.013	-0.015	-0.002	-0.031
Collective soil & water conservation	0.004	0.022	0.886	-0.024	-0.001	0.026
Share labour during shortage	-0.026	-0.054	0.024	-0.018	0.755	-0.028

Sell produce collectively	0.031	0.004	0.038	0.014	0.103	-0.058
Trust villagers	0.044	0.060	0.036	0.284	0.118	0.040
Trust traders	-0.093	-0.095	-0.121	0.507	-0.165	-0.075
Trust extension workers	0.087	0.074	-0.061	0.245	-0.031	0.046
Trust NGOs	-0.010	-0.077	0.184	0.004	-0.072	0.742
Trust gram panchayat	0.005	0.013	0.081	0.254	0.017	0.126
Trust lenders & borrowers	0.024	0.012	0.069	0.331	0.162	-0.007
Provide unpaid volunteer work on other farmers' land	0.038	0.075	-0.212	-0.104	0.462	0.044
Support fellow farmers' credit needs	-0.005	0.052	-0.049	0.452	-0.075	-0.021
APCNF worker's support	0.686	0.004	-0.008	-0.007	-0.022	0.023

Source: Compiled by author.

Table 24: Social capital in CNF villages & non-CNF villages

Variable	Non-CNF villages (obs = 278)	CNF villages (obs = 279)	Combined (no. obs = 557)	H0: diff =0 Difference (t-stat)	Ha: diff > 0 Pr (T>t)
Social capital index	21.962	30.905	26.441	-8.94 (-29.07)	1.00
Information provision	0.2013	6.200	3.206	-5.99 (-89.33)	1.00
Mutuality	0.994	2.03	1.513	-1.03 (-7.37)	1.00
Collective action	2.06	2.093	2.073	-0.019 (-0.14)	0.557
Trust & support	8.65	9.27	8.96	-0.618 (-5.13)	1.00
Community cohesion	5.072	5.79	5.43	-0.721(-6.39)	1.00
Risk reduction	4.97	5.52	5.24	-0.547(-4.99)	1.00

Source: Author's estimate.

Table 25: Value of different dimensions of social capital by village

Village	Information provision	Mutuality	Collective action	Trust & support	Community cohesion	Risk reduction	Social capital index
Semi-arid area							
Amadalagondi (non-CNF village)	0.161	0.562	2.923	8.691	4.557	4.868	21.761
Gunduvaripalli (CNF village)	**5.89**	**1.33**	**2.58**	**9.27**	**5.50**	**5.679**	**30.249**
Melavoi (CNF village)	**6.164**	**0.522**	**3.238**	**8.942**	**5.351**	**5.839**	**30.057**
Mohammadabad (non-CNF village)	0.178	0.701	3.550	8.450	3.985	5.321	22.185
Tribal area							
Durubili (CNF village)	**5.830**	**3.722**	**2.371**	**7.519**	**6.896**	**5.542**	**31.880**
G. Sivada (non-CNF village)	0.297	2.696	1.650	8.646	6.732	5.707	25.728
Gujjuvai (non-CNF village)	0.252	2.004	2.000	8.829	6.400	5.763	25.248
Kondabaridi (CNF village)	**6.653**	**3.669**	**1.968**	**9.373**	**7.330**	**6.986**	**35.979**
Godavari delta area							
Singaram (non-CNF village)	0.191	0.894	0.878	8.649	5.261	4.538	20.412

Ammapalem (CNF village)	**6.567**	**3.190**	**0.788**	**9.720**	**5.552**	**5.109**	**30.927**
Kapavaram (CNF village)	**6.212**	**1.610**	**1.747**	**9.769**	**5.961**	**4.878**	**30.176**
Kumaradevam (non-CNF village)	0.217	0.715	1.151	8.713	5.200	4.584	20.580
All farms & villages	3.2063	1.5136	2.0737	8.9618	5.4386	5.2478	26.442
Village	Information Provision	Mutuality	Collective action	Trust & support	Community cohesion	Risk reduction	Social capital index

Source: Compiled by author.

4.5 Factors facilitating social capital formation in different villages (Objective 2)

In this section, we analyze Objective 2: Using regression analysis, we assess the factors facilitating the generation of social capital at the farmer's level, where the social capital index is used as a dependent variable and the farming community's demographic, economic, and social indicators, along with farm and village level characteristics, are used as explanatory variables. We used ordinary least squares for estimation and performed the required corrections for heteroscedasticity. The literature governs the selection of the variables. Table 26 gives the descriptive statistics of the variables used in the regression analysis. The regression analysis also analyzed how women benefited from CNF and how CNF benefitted from women's participation.

Table 26: Descriptive statistics of sampled villages

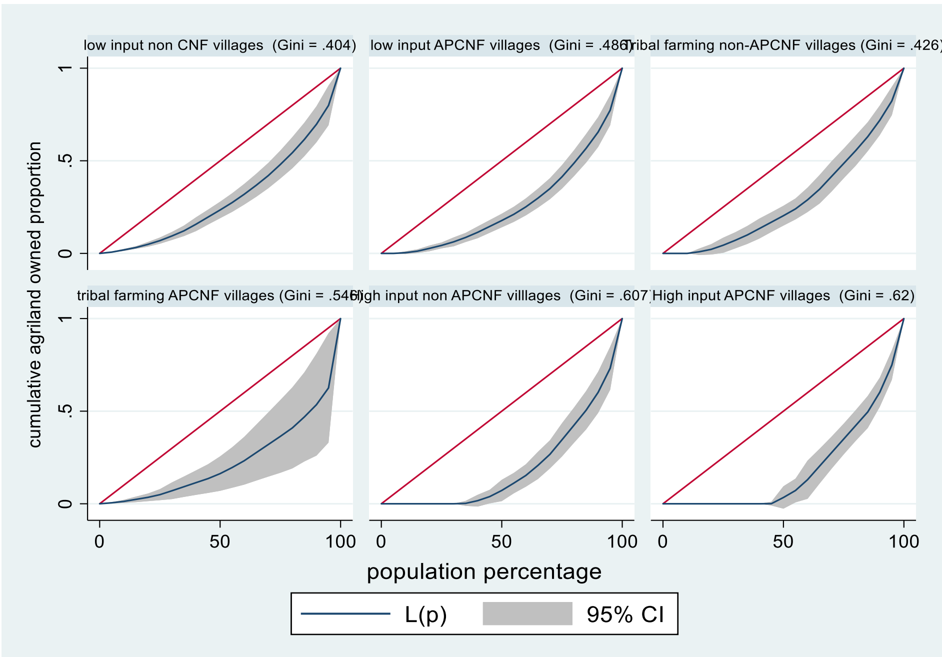
Village	Tribal farming area	CNF area	Member farming group	Member SHG	Education	Gender	Average age	Income (INR)	CNF (years)	Value of production (INR)
Amadalagondi	0	0	0	0.77	1.73	1.76	48.74	194,973	0.00	50,529.44
Ammapalem	-	1.19	0.59	0.95	2.16	1.05	46.55	126,369	3.58	87,443.31
Durubili	-	1.26	0.75	0.92	1.67	1.79	41.75	70,008	8.79	30,906.40
G. Sivada	0.21	0.00	0.58	1.00	1.79	1.58	44.00	102,048	0.00	30,047.50
Gujjuvai	0.28	0.00	0.37	0.96	1.71	1.58	47.83	124,104	0.00	47,710.75
Gunduvaripalli	-	3.47	0.40	0.90	2.43	1.63	44.10	243,185	3.67	91,452.16
Kapavaram	-	1.66	0.27	0.80	2.38	1.13	45.80	153,720	3.05	152,764.90
Kondabaridi	-	1.35	0.62	0.96	2.00	1.83	45.08	135,658	5.00	43,632.17
Kumaradevam	0.00	0.00	0.03	0.74	2.03	1.07	51.72	247,768	0.00	604,053.20
Melavoi Papasa	-	2.50	0.10	0.97	2.21	1.85	45.68	260,640	5.56	88,658.46
Mohammadabad	0.00	0.00	0.02	0.90	1.90	1.28	50.94	172,589	0.00	51,311.79
Singaram	0.00	0.00	0.05	0.97	1.90	1.07	45.52	215,789	0.00	229,316.00

Source: Author's estimates.

Table 26 shows significant differences across the villages regarding the demographic, social, and economic variables. The average age of the respondent varied from 40 to 51 years. In some of the villages – Durubili, Gundivaripalli, Kapavaram, Kondabaridi, and Melavoi Papasa – the farmers have been practising CNF for more than 3 years. The average income varied between INR 70,000 to INR 260,000, showing huge variation in livelihood conditions. The production value varied widely between INR 30,900 to INR 604,000. In addition, some villages have very active farmers' networks, while others do not; similarly, some farmers very actively practise CNF. The farmers, on average, had completed their secondary education. The explanatory variable showed social capital formation considerably well (via the high R-square). The heteroscedasticity corrected regression model has been fitted, considering the cross-sectional nature of the data. Several interesting results were found from the model: The higher the agricultural land owned, the lower the social capital index, thereby showing that smallholder farmers are active in generating social capital. Figure 13 gives the distribution of landholdings among the sampled population by six village groupings. The higher the

Gini coefficient,[1] the higher the inequality in landholdings. The villages that practised high-input (chemical) farming had higher inequality in landholdings. The variable agricultural land owned is negative and statistically significant at 10%.

Figure 13: Distribution of agricultural land owned in different villages classified by farming system



Source: Author's estimate.

[1] The Gini index measures the extent to which the distribution of income or consumption among individuals or households within an economy deviates from a perfectly equal distribution. A Gini index of 0 represents perfect equality, while an index of 100 implies perfect inequality. Landholdings are used a proxy for income in the study.

On the other hand, the higher the amount of land holding under CNF, the higher the level of social capital. The value of crops produced did not have any impact on the social capital formation. Gender of head of household and whether the farmer is a member of the farming group have a positive and significant impact on the social capital (significant at 1% level). Households being part of self-help groups had a positive and significant impact on the social capital, as the CNF volunteers targeted SHG women members to spread the message of natural farming. Women usually do not take part in the farming decisions. However, they would influence men about natural farming. All three variables – farmers being part of the farming network, gender, and being part of SHG – were positive and highly significant. Education also had a positive impact on social capital formation. Thus, CNF has succeeded in building social capital among the villagers, and women significantly influenced social capital formation at the farmers' level.

Table 27: Results of the regression analysis assessing factors facilitating social capital

Dependent variable (log social capital)	Coefficient	t-ratio
Household size	0.0058*	1.49
Household income	-9.29e-09	0.21
Agricultural land owned	-0.0047**	-1.75
CNF village (dummy)	0.233***	12.30
Area owned under CNF	0.009*	1.39
Age of head of household	0.001*	1.80
Gender	0.0462***	3.26
Education	0.01003*	1.60
Agricultural production value	1.21e-09	0.07
Member farming group	0.110***	6.80
Member SHG	0.038**	1.80
Constant	2.848***	67.22
R-square **F (11, 547)** **No. of observations**	0.52 54.26 557	

Note: * Significance 10%
** Significance 5%
*** Significance 1%

Source: Author's analysis.

4.6 Is there a relation between the social capital index & productivity gains (Objective 3)?

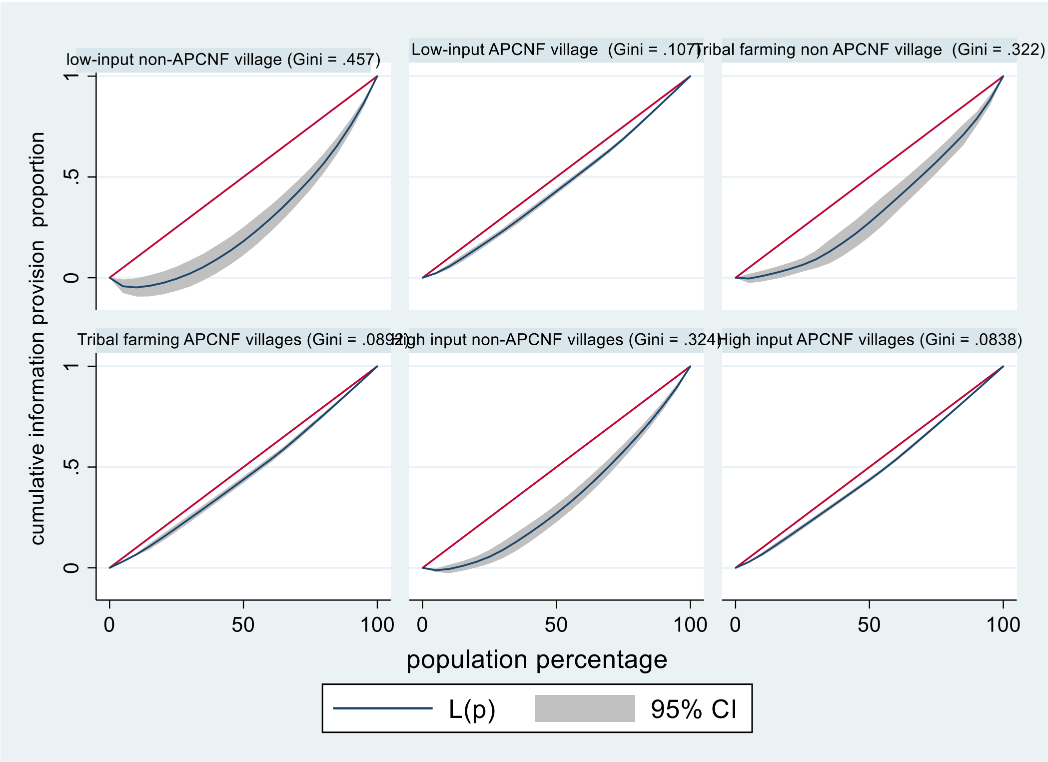
Objective 3 of this study is to quantify by how much the social capital benefitted the farming community. This has been measured by assessing the productivity gains for the farming community. Farmers face many hurdles and constraints due to lack of quality seeds, labour shortages during the seasons, and lack of technical know-how and irrigation facilities. We hypothesize that social capital does help in overcoming some of these barriers and contributes to productivity gains. The hypothesis here is that farmers with better social capital have higher productivity. Literature has reported that organized farmers have significant gains in productivity when compared to unorganized small-scale farmers. Thus, an ordinary least squares estimation has been carried out with the value of production as the dependent variable and various social capital components along with other farm productivity determinants separately for both CNF and non-CNF villages. As it is essential to assess which dimension of social capital is more beneficial to the farmers, we estimated two different regression models.

In model 1, the aggregate social capital index was considered one of the explanatory variables, while in model 2, we considered the five components of social capital (instead of the aggregated social capital index). The regression has been carried out separately for the CNF and non-CNF villages to understand the differential returns of social capital. Both models included relevant socioeconomic and demographic variables as control variables.

Table 27 presents the results of the two models for CNF and non-CNF villages. The results of the multiple regression show that in CNF villages, social capital positively contributed to productivity, whereas in non-CNF villages, social capital is negatively related to the value of production. Non-CNF villages have a large number of farmers practising chemical-intensive farming. The analysis was also conducted to understand which component of social capital largely contributed to productivity. Interestingly, trust and reciprocity became highly significant in CNF villages. Earlier results also show that trust plays an important role in facilitating cooperation and supporting a long-term relationship among individuals, reducing transaction costs (Lyon, 2000).

Community cohesion positively and significantly impacts farm productivity in CNF villages. While information provision negatively influenced productivity in non-CNF villages, it had a positive and significant influence on productivity in CNF villages, showing that information sharing had a valuable role in providing technical know-how, thereby improving the production levels. In CNF villages, the volunteers actively engaged with the farmers in providing relevant technical information. This can be seen from Figure 14, in that the inequality in information support is lowest in villages practising community farming. Community cohesion's strong and positive influence on productivity gains shows that farmers gain by cooperating rather than farming individually. This is because labour and other resources are shared through collective action, reducing conflict, and adding efficiencies.

Figure 14: Distribution of information support in various villages classified by farming system



Source: Author's analysis.

Table 28 shows that household size in all the models has negatively contributed to production value, while income is positively related to productivity (farmers may have limited financial resources to make adequate farm investments). Gender and age negatively and significantly impact the value of production, showing that women do not necessarily prioritize high-value crops, while men may plant high-value crops (see Table 28). Younger farmers tend to have better ideas than older farmers rooted in traditional farming systems. We also found that the villages that practised CNF had lower levels of information and lower inequality (as seen in Figure 14). The important implication is that social capital can compensate for lack of education and experience by enabling these farmers to gain through networking, hence impacting productivity.

Table 28: Factors influencing production value in CNF & non-CNF villages

Dependent variable (log value of Production)	Model 1	Model 2	Model 1	Model 2
	Non-CNF village		CNF village	
Social capital index	-0.095*** (-4.77)	—	0.033*** (2.83)	—
Information provision	—	-0.77** (-1.6)	—	0.07** (1.77)
Mutuality	—	-0.11 (-0.62)	0.02 (1.51)	0.02 (0.51)
Collective action	—	-0.37*** (-7.55)	—	-0.07** (-1.86)
Trust & support	—	0.07 (1.29)	—	0.12*** (3.28)
Community cohesion	—	0.04 (0.7)	—	0.05* (1.33)
Risk reduction	—	-0.15** (-2.12)	-0.03 (-0.92)	—
Household size	-0.185 (-3.56)	-0.17*** (-3.88)	-0.051*** (-2.17)	-0.04 (-1.81)
Income	0.000*** (9.25)	0.00*** (9.41)	0.000 (1.38)	0.00 (1.41)
Agricultural land owned	0.013 (0.65)	0.04 (1.33)	-0.044*** (-1.91)	-0.04 (-1.74)
The area under NCF	—	—	0.30 (6.79)	0.30 (6.63)
Age	-0.012** (-1.99)	0.00 (-0.7)	-0.002 (-0.65)	0.00 (-0.47)
Gender	-1.116*** (-6.65)	-0.85 (-5.14)	-0.850** (-8.48)	-0.64 (5.5)
Member of farming group	0.748*** (2.97)	0.44 (0.72)	-0.163** (-1.51)	-0.15 (-0.83)
Constant	15.087 (26.77)	13.13 (22.0)	10.99 (29.07)	10.01 (21.32)
R-square	0.391	0.50	0.395	0.44
F	34.040	34.00	18.930	17.21
Df	7	12.00	8.000	13.00
N	268	263.00	263.000	258.00

The results indicating that social capital positively influences farm productivity are consistent with the literature (Jaime, 2011; Serra, 2015). These results suggest that rural people benefit significantly from social capital as much as other endowments, such as labour and physical and human capital. The results indicated that the higher quantity of agricultural land owned, the higher the productivity but lower the value of production in the CNF villages, while the value of production is higher in non-CNF villages. This is because the nature of crops grown varied between the two village types. More diverse crops are grown in CNF villages compared to non-CNF villages, and the CNF villages did not focus on the commercial value of the crops. A significant number of villagers grew the crops for self-consumption.

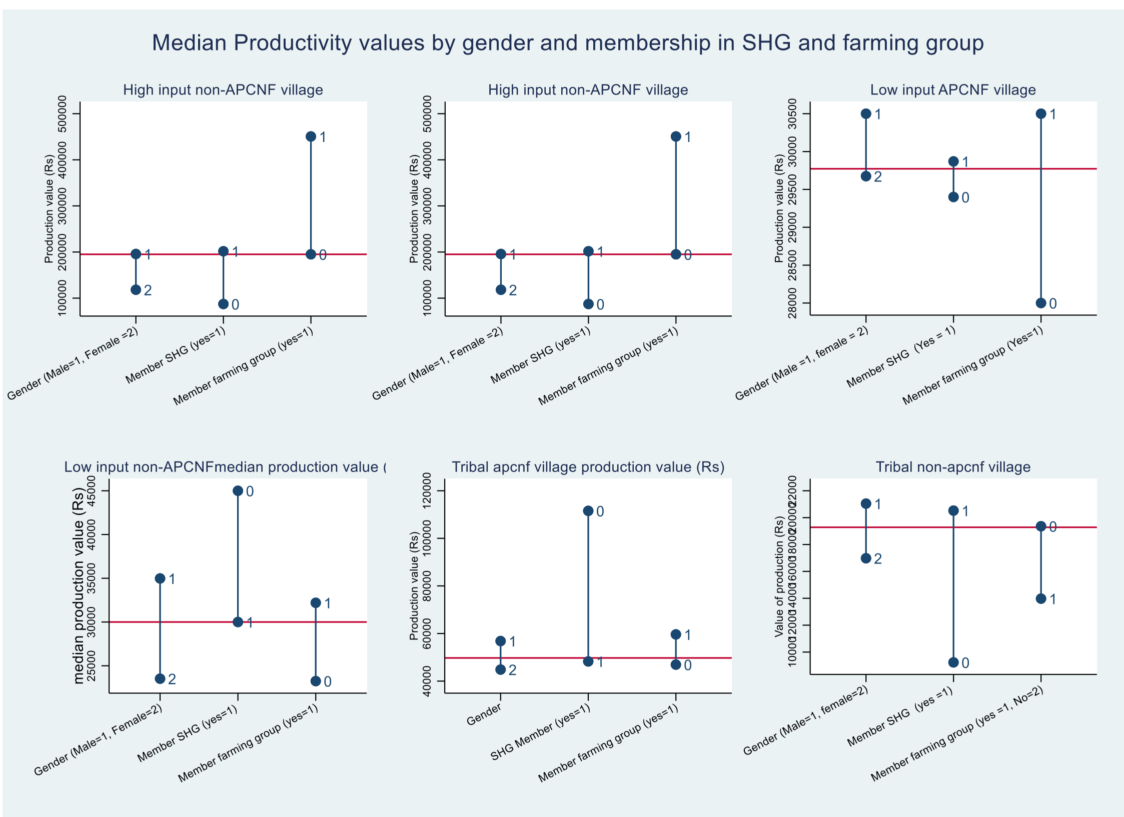
4.7 Role of women in influencing the social capital & productivity (Objective 4)

We have established that social capital is an important factor for the success of CNF. Due to their responsibilities for family and concern for the well-being of the future generations, women typically take up the role of local managers (Westermann, 2005). In this objective, we look explicitly at the role women play in the formation of social capital and, hence, in reaping the gains from CNF. A number of studies have shown that women are strong collaborators, as daily they are more interdependent, make stronger bonds, and operate in informal networks (Agrawal, 2000). In the study area, women usually did not take part in the farming decisions. However, they would influence men about CNF.

In this study, the active role played by women is captured through three variables: membership in the self-help group (SHG), perception of how actively they take part in the SHGs, and the gender of the respondent. The ability to influence men in decision-making is captured through the variable – whether the households are members of a farming group and whether women are consulted in farming decisions. Figure 14 presents the mean differences in social capital and productivity differences by gender as well as membership in farming groups and SHGs in the three categories of villages.

The results indicate that women play a significant role in enhancing household-level social capital. Women are passive decision-makers and influence the households through information provided in SHGs. The SHG community influences the men in the family to adopt CNF. Significant differences in social capital exist across all three categories considered: being part of the farming network, gender, and being part of a SHG. The social capital is higher in all three categories. The differences are quite significant in high-input villages (between CNF and non-CNF villages). Similarly, productivity differences exist across the six types of villages. While productivity is higher in non-CNF villages, across the three categories we see significant differences between farms who take part in SHGs and farming groups.


Median social capital index by Gender and membership in SHG and farming groups
High input apcnf village
Social capital index
Gender
Member SHG
Member farmingroup
High input non APCNF village
Social Capital Index
Gender (1=male, 2= female)
SHG member (yes =1)
Member farming group (yes=1)
low input APCNF village
Social capital index
Gender (1=male, 2= female)
SHG members (Yes = 1, No=0))
Member farming group (Yes = 1)
Low input non APCNF village
Social Capital Index
Gender (1=Male, 2 = female)
SHG membership (1=yes)
Member farming group
Tribal APCNF villages
Social Capital Index
Gender (1=male, 2=female)
Member SHG (1=yes)
Member farming group (1=yes)
Tribal Non-APCNF village
Social Capital Index
Gender (1=male, 2= female)
SHG membership (1=yes)
Member Farming group (1=yes)


Median Productivity values by gender and membership in SHG and farming group
High input non-APCNF village
Production value (Rs)
Gender (Male=1, Female =2)
Member SHG (yes=1)
Member farming group (yes=1)
High input non-APCNF village
Production value (Rs)
Gender (Male=1, Female =2)
Member SHG (yes=1)
Member farming group (yes=1)
Low input APCNF village
Production value (Rs)
Gender (Male =1, female = 2)
Member SHG (Yes = 1)
Member farming group (Yes=1)
Low input non-APCNFmedian production value (
median production value (Rs)
Gender (Male=1, Female=2)
Member SHG (yes=1)
Member farming group (yes=1)
Tribal apcnf village production value (Rs)
Production value (Rs)
Gender
SHG Member (yes=1)
Member farming group (yes=1)
Tribal non-apcnf village
Value of production (Rs)
Gender (Male=1, female=2)
Member SHG (yes =1)
Member farming group (yes =1, No=2)

4.8 Conclusions & policy implications

The results of the analysis show that the CNF community sustains social capital. Although social capital is a complex concept to measure, the present study constructed a comprehensive social capital index at the farmers' level using a multidimensional framework for three districts in Andhra Pradesh. The study confirms that social capital has positive productivity gains for the farmers and that women play a crucial role in facilitating community farming.

The results show quite an interesting pattern. The means test indicated that the comprehensive social capital index is significantly higher in villages practising CNF than in non-CNF villages (see Table 24). Of the various dimensions of the social capital, information provision, collective action, and perception to risk significantly influence productivity. However, the study results showed that these three dimensions of social capital were insignificant for the farmers not practising CNF. The study also found that women play a significant role in enhancing the region's social capital, as women are passive decision-makers in farming. The SHG community in which CNF workers are members influence the men in the family to adopt natural farming. The study also showed that smallholder and marginal farmers benefit from the social capital and collectively from farming more than prosperous farmers.

Agricultural policies need to consider the creation of social capital among the farmers as an integral part of the planning process and emphasize connectedness with nature as the core of farming. This can enable the farmers to better harness the opportunities created by collective action and information provision. Some effort is required to encourage collective action among the farmers. Collective action facilitates sharing of farm inputs (including expensive technology). For example, borewells are expensive to install, and not all farmers can afford them. However, collective action and community support might enable farmers to share expensive technologies that otherwise are untenable for smallholder farmers. Social capital does not mean ensuring cooperation at the farmers' level alone but is also required at all levels – communities, governments, supply chains, etc. Cooperation and collaboration among all these actors are essential for sustainable natural farming. Such movements are taking shape in various states, including Andhra Pradesh, Karnataka, Maharashtra, Haryana, Gujarat, Himachal Pradesh, and Kerala. However, more impetus is required to leverage the potential of social capital for mass-scale adoption of CNF.

5 Valuing the on-farm human health impact & food-plate diversity of farmer households in CNF

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Take-home messages

1) Improving farmers' access to information is key to avoiding the dangers associated with chemical inputs and for reducing potential pollution of agricultural systems.
2) Recommendations for personal protective equipment and precautionary practices to avoid direct contact with chemical inputs during preparation and application are well documented but not widely practised.
3) Using chemical inputs such as pesticides and fertilizers leads to higher incidents of short-term symptoms due to exposure. This, in turn, leads to material health costs and productivity losses, which are a negative externality for farmers and unaccounted in the traditional market-based crop-pricing models.
4) CNF farmer households consume more varied diets compared to their counterparts; despite this, no household (CNF nor counterfactual) consumes a complete diet.
5) The role of subsidies is a key determinant in adoption of existing agricultural practices. In the absence of holistic measures of the true cost of food – i.e., the environmental, human, social, and financial costs – stakeholders cannot make informed choices.

5.1 Introduction

The world's agri-food systems comprise a gargantuan global enterprise that each year produces approximately 11 billion tons of food (FAO, IFAD, WHO, 2017). In 2021, an estimated 770 million people, almost 10% of the global population, suffered from hunger, an increase of nearly 150 million compared to 2019, and 210 million compared to 2015 (FAO, 2020). Currently, 41.9% of the global population are unable to afford a healthy diet (FAO, *State of Food and Agriculture,* 2019). According to estimates compiled by the Food and Agriculture Organization (FAO), by 2050 we will need to produce 60% more food to feed a world population of 9.3 billion.

Although agriculture at the global level has become more efficient, in recent decades competition for natural resources has intensified owing to consumption patterns driven mainly by population growth, changing dietary patterns, industrial development, urbanization, and climate change. In the last 10 years, the frequency and intensity of conflict, climate variability and extremes, and economic slowdowns and downturns have increased and are undermining food security and nutrition around the world. Of particular concern are low- and middle-income countries – the negative impacts on food security and nutrition are greatest in these countries, and they carry the biggest burden of the world's population who are undernourished, food insecure, and suffer from one or more forms of malnutrition. Total production of primary crops increased by almost 50% between 2000 and 2018, to 9.1 billion tons in 2018 (FAO, 2020).

This study uses the TEEBAgriFood Evaluation Framework to focus on three distinct agroecological zones across the state of Andhra Pradesh – tribal, semi-arid, and the Krishna-Godavari basin areas – each represented by sets of farmers who apply CNF and local agricultural practices (chemical-intensive farming, dryland/rainfed agriculture systems, tribal organic farming). This study also analyzes and compares the human health impacts of these alternative farming methods by testing for correlations between farm input-use and occurrence of ill health, and by estimating the total economic cost (i.e., negative health externalities) due to need for medical treatment, and loss of wages due to losses in productivity.

5.1.1 Agricultural practices & diets in India

The large-scale adoption of chemical-intensive farming has enabled farmers to increase yields, but the nutritional quality of crops grown and its impact on environment remain in question. It is a matter of concern that, despite achieving sufficiency in food production, India has over 189.2 million undernourished people, with 40.3% of children under 5 years suffering from stunting and 20.1% of children under 5 years suffering from wasting (FAO, IFAD, UNICEF, WFP, and WHO, 2020).

According to WHO, healthy diets protect against malnutrition in all its forms, including non-communicable diseases such as diabetes, heart disease, stroke, and cancer. Healthy diets contain a balanced, diverse, and appropriate selection of foods consumed over time. In addition, a healthy diet ensures that a person's needs for macronutrients (proteins, fats, and carbohydrates, including dietary fibre) and essential micronutrients (vitamins and minerals) are met, specific to their gender, age, physical activity level, and physiological state. Healthy diets include less than 30% of total energy intake from fats, with a shift in fat consumption away from saturated fats to unsaturated fats and the elimination of industrial trans fats; 10% of total energy intake from free sugars (preferably less than 5%); consumption of at least 400 grams of fruits and vegetables per day; and less than 5 grams per day of salt (to be iodized).

While the exact make-up of a healthy diet varies depending on individual characteristics, as well as cultural context, locally available foods, and dietary customs, the basic principles of what constitutes a healthy diet are the same. In 2019, healthy diets were still unaffordable for approximately 3 billion people in the world (FAO, 2020). The inability of food systems to provide households with adequate access to nutritious foods that contribute to healthy diets – especially in the aftermath of containment measures aimed at stemming the still-ongoing COVID-19 pandemic – has amplified the call for a transition of food systems to make healthy diets available and affordable to all (FAO, 2020).

Agriculture affects nutrition through six major pathways as recognized by Kadiyala et al. (2014) (see Figure 15):

1) Agriculture as a source of food.
2) Agriculture as a source of income for food and non-food expenditures.
3) Agricultural policy and food prices.
4) Women in agriculture and intrahousehold decision-making and resource allocation may be influenced by agricultural activities and assets, which in turn influences intrahousehold allocations of food, health, and care.

5) Maternal employment in agriculture and childcare and feeding.
6) Women in agriculture and maternal nutrition and health status.

Studies show that crop diversification has a positive association with dietary diversification (Bhagowalia, 2012; Galab, 2011; Kataki, 2002; and Wani et al., 2012).

Prior to the Green Revolution, the Indian diet primarily consisted of vegetables (20.1%), fruits (18.3%) and cereals (12.3%) (Longvah, 2017). Millets were also a traditional staple food, but its consumption declined drastically after the Green Revolution, and it's now used mainly as fodder (Nelson et al., 2019). Since 1939, India has measured the nutritional value of its foods using the Food Composition Table (FCT) – which collates data on the chemical constituents, energy yield, and nutritive value of food based on chemical analysis (see

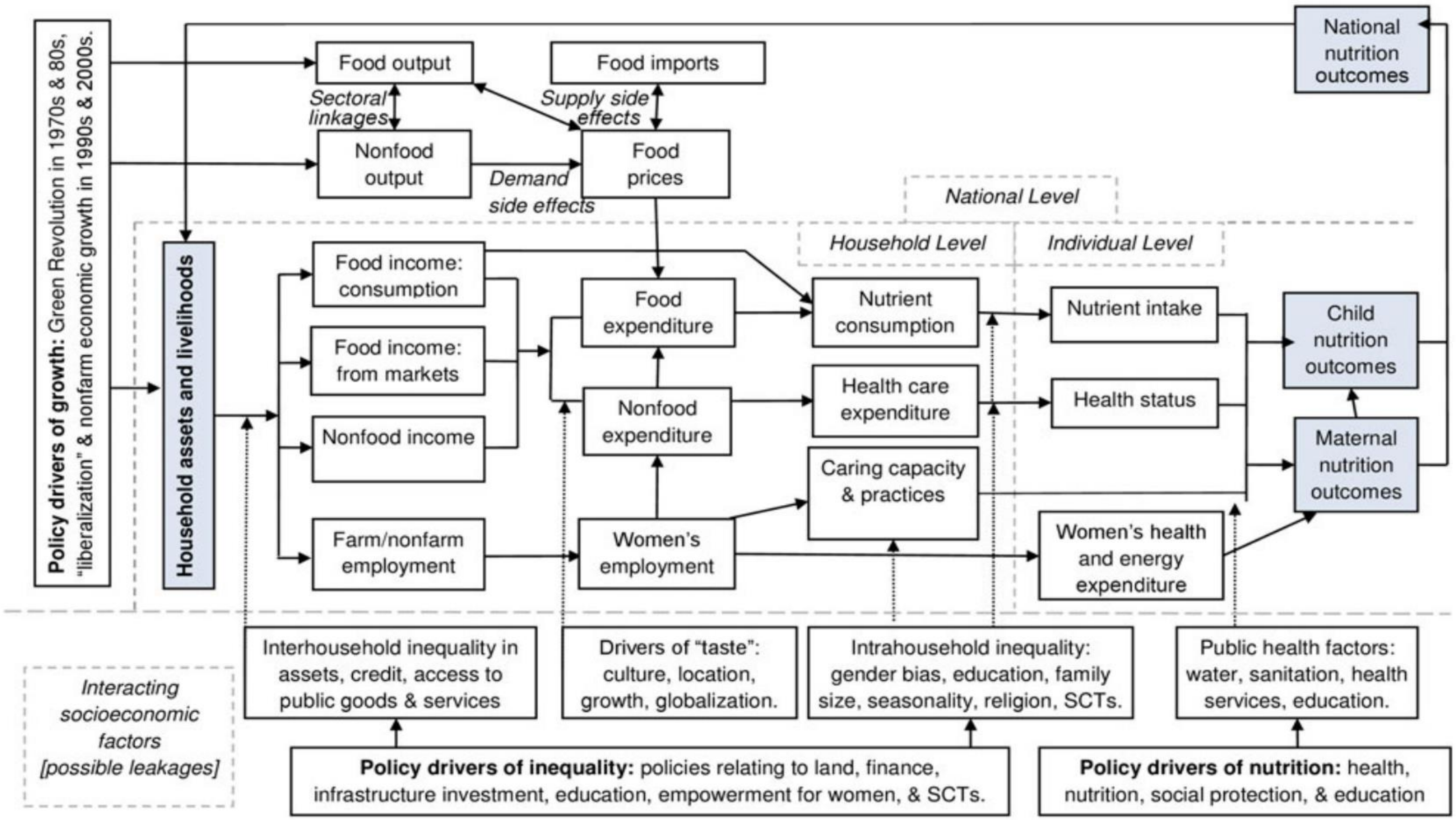
Figure 16). Between 1939 and 2017, along with declining food-plate diversity, nutrient content has declined significantly in cereal, pulses, vegetables, and fruits. Chemical analysis conducted by NIN Hyderabad shows that protein levels in green gram and black lentil have reduced by 10 and 6.2%, respectively. Also, levels of thiamine, magnesium, and zinc in tomatoes, cabbage, and roots and tubers have declined by 41 to 67%, while fruit has lower levels of vitamin C, thiamine, and carotene, ranging from 6.4 to 22.7%. Also, carbohydrates in green leafy vegetables have significantly declined, by 12%. On a positive note, micronutrient levels have risen in foods like masoor and green leafy vegetables, and potato contains more iron than before (Shukla, 2016).

Conventionally (chemical-intensive cultivation) grown foods are also less nutritious and have lessor number of protective antioxidants (Das, 2020). Various scientific studies and surveys conducted on fertilizer and pesticide residues during last 45 years indicate the presence of residues of fertilizers and pesticides such as nitrates, organochlorines, organophosphates, synthetic pyrethroids, and carbamates at higher levels than permissible limits in milk, dairy products, water, fodder, livestock feeds, and other food products (Rahman, 2015). Some of the underlying factors behind this decline in nutritional quality of India's food include:

- Excessive use of chemical inputs and the resulting chemical degradation in soil and water quality, including the accumulation of heavy metals in soil and plant systems (Savci, 2012).
- Increased levels of carbon dioxide in the atmosphere, which impacts plant nutrition by inhibiting nitrogen uptake (Taub, 2010; Ainsworth, 2005).

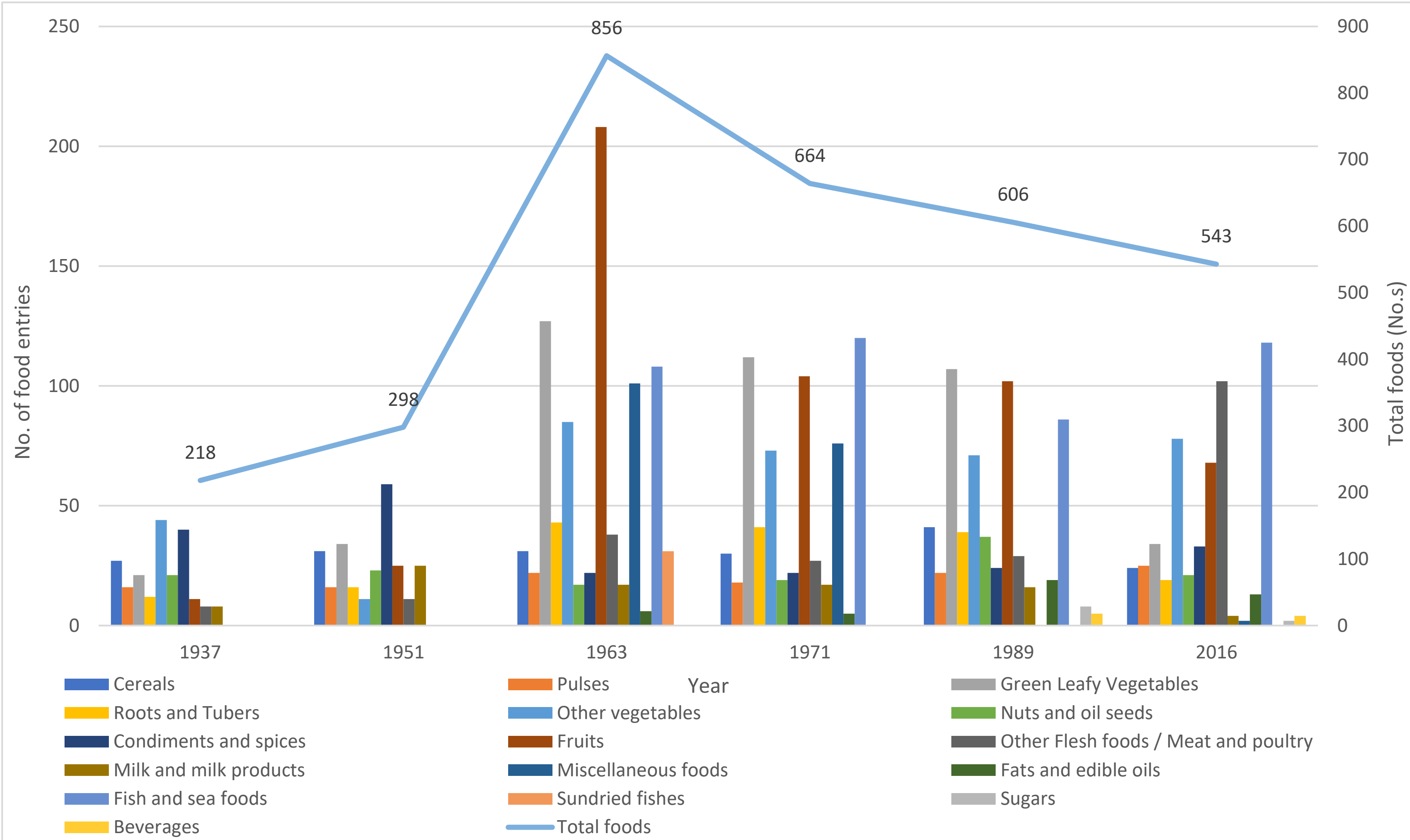
Overall, in India, policies that promote staple crop production, such as fertilizer and credit subsidies, price supports, and irrigation infrastructure (particularly for rice), have tended to discourage the production of traditional non-staple crops, such as pulses and legumes (Pingali, 2015).

Figure 15: Mapping of agriculture–nutrition pathways in India



Source: Kadiyala et al., 2014.

Figure 16: Indian food consumption table (1937–2017)



Sources: Aykroyd, 1937, 1951, 1956, and 1963; Gopalan, 1971 and 1989.

5.1.2 Evidence from literature: Human health impact of chemical-intensive farming practices in India

In developing countries, farmers practising chemical-intensive cultivation face greater risks of exposure to toxic chemicals than farmers in developed countries, where more chemicals are banned or restricted. Moreover, health hazards are increased by incorrect application techniques, poorly maintained or totally inappropriate spraying equipment and inadequate storage practices (Asogwa, 2009). The same can be said for farmers in India.

Exposure to chemicals during farming activities may be linked to chronic diseases such as cancer and respiratory, reproductive, and neurological diseases. While sustainable (organic and natural) farming practices also pose occupational hazards (biological and health), the risks are significantly higher in conventional (chemical) farming (Krishnaveni, 2019). Most agricultural occupational hazard studies focus on conventional farming practices.

Agricultural workers may be directly exposed to chemicals while preparing and applying chemicals/manure, consuming contaminated food and water, and inappropriately handling chemicals/manure. Local communities may be affected via water body contamination through run-offs and proximity to agricultural fields and toxic aerosols (Mittal, 2014).

Occupational hazards on farm, such as accidents and equipment-related injuries, are also an issue. Such hazards arise irrespective of the farming method and generally relate to farming tools used. Fatal and severe accidents occur in mechanized farming (prevalent in chemical-intensive farming) – e.g., collisions with machines, getting caught in moving or rotating equipment, rollover/runover by machines – which often results in multiple organ damage, cerebral injuries, and traumas (Robert, 2015; Rorat, 2015). Commonly reported non-fatal injuries due to improper use of farming tools and lack of protective gears and equipment include cuts, punctures, lacerations, and factures. Foot, ankle, knee, finger, and limb injuries are some of the most common (Bhattarai et al., 2016; Patel, 2018; ÜNAL, 2008).

Studies have linked numerous adverse health impacts – neurological, carcinogenic, respiratory, and reproductive – to exposure to agricultural chemicals (Dhananjayan, 2018). Table 29 lists the most common occupational hazards associated with both chemical and natural/organic farming, as distilled from over 100 published research studies and articles.

Table 29: Diseases & disorders associated with chemical & natural/organic farming

Farming system	Cause	Effects	Disease & disorders
Chemical	Direct exposure	Neurological	Parkinson's disease, damaged cells and DNA, reduced cognitive and motor skills, sleep disorders
Chemical	Direct exposure	Carcinogenic	Lungs and breast cancers, multiple myeloma
Chemical	Direct exposure	Respiratory	COPD, shortness of breath, asthma, nasal congestion, sleep apnea
Chemical	Direct exposure	Reproductive	Altered reproductive hormone levels, degraded semen morphology
Chemical	Direct exposure	Other chronic and acute effects	Skin irritation, burning and red eyes, nausea, dizziness, thyroid disorders, dermatoses, fungal infections
Organic/Natural	Direct exposure	Gas induced	Severe lung, eye, and nose irritations; loss of appetite; collapse; and respiratory paralysis
Organic/Natural	Indirect exposure	Pathogenic	Diarrhea, hemorrhagic colitis, fever, stunting, heat burn, and constipation
Organic/Natural	Direct exposure	Other acute and chronic effects	Dermatological disorders, nasal irritation, backaches

Source: Compiled by author.

5.2 Methodology

5.2.1 Key objectives

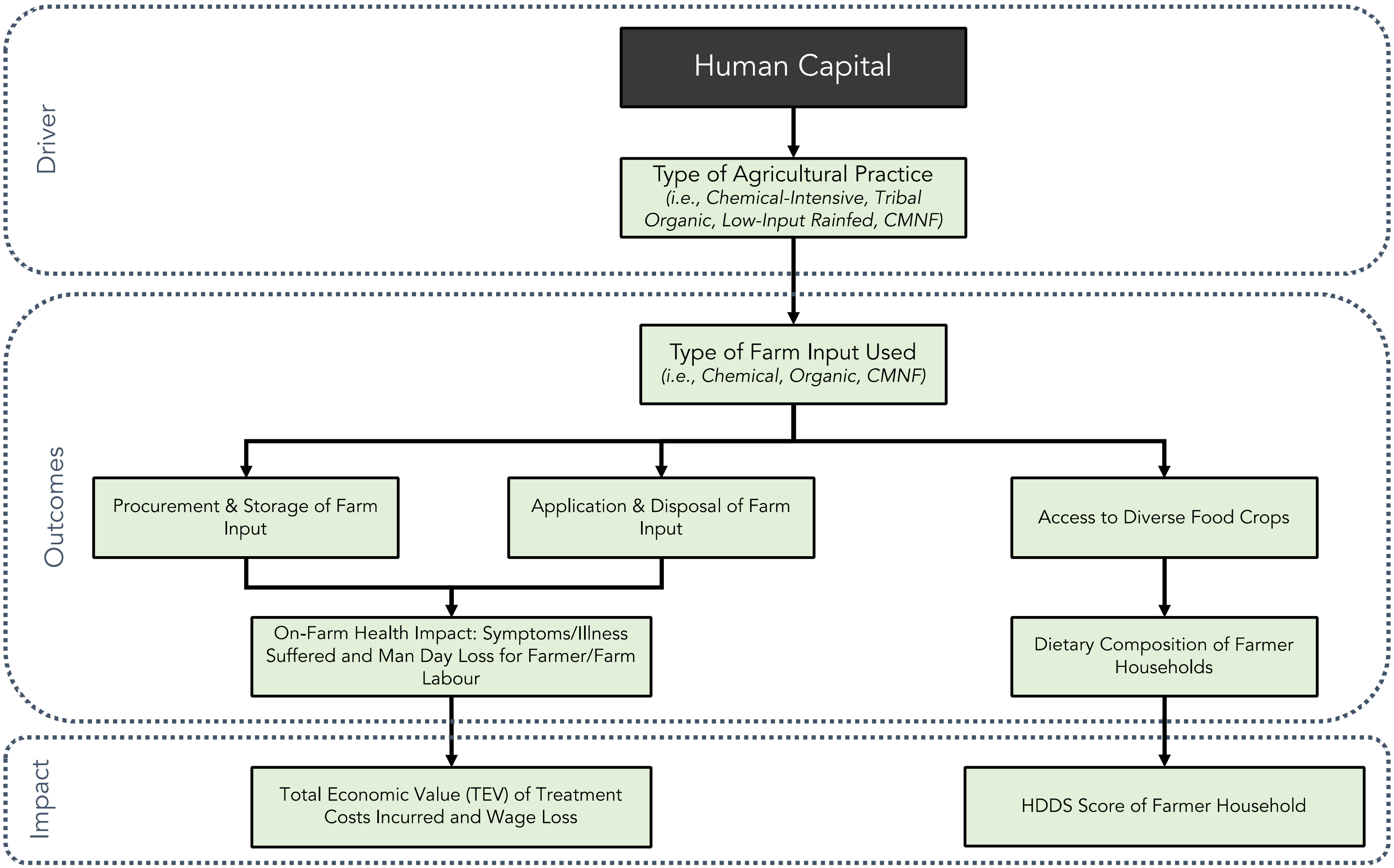
Using the TEEBAgriFood Evaluation Framework, this section compares CNF practices with alternative farming practices adopted by farmers in order to meet the following key objectives:

- To analyze agricultural input-use for tribal, rainfed, chemically intensive, and CNF agricultural practices across three agroecological regions in Andhra Pradesh.
- To understand farmer awareness regarding the health impacts/side effects associated with the procurement, storage, application, and disposal of chemical, organic, and CNF inputs.
- To determine the marginal increase in the prevalence of symptoms of toxic exposure that can be attributed agricultural practices adopted by farmers.
- To estimate the marginal increase of the total economic value (TEV) of treatment costs and productivity losses for farmers and farm labourers attributable to on-farm exposure to agricultural inputs.
- To analyze the relationship between household diet and agricultural practices for farmer households.

5.2.2 Framework for measuring health impacts on farmers & farm labourers associated with farming practices

In this section, we measure on-farm human health impacts and impacts of farmer households' diets using a Drivers>Outcomes>Impact framework.

Figure 17: Framework for estimating the human capital impact of CNF & counterfactual agricultural practices in Andhra Pradesh



Source: Compiled by author.

5.2.2.1 Estimating the total economic value of on-farm health impact

In our current assessment we use multivariate linear correlation analysis to test for relationship between type of agricultural practice adopted; type and quantity of farm input used; storage, application, and disposal methods practised; and the prevalence of symptoms of short-term and long-term toxic exposure in farmers and farm labourers.

In addition to that, we also estimate the total economic value of loss incurred by households for CNF and counterfactual agricultural method practising farmers. This is estimated by aggregating the average treatment costs/cost of illness for material ailments incurred by farmers, and the opportunity cost of productivity loss (measured via wages lost) due to work days lost as a result of ailments caused by exposure to farm inputs.

$$\text{TEV of Health Impact} = ((C1_{i1v1} * D1_{i1v1}) + (C2_{i2v2} * D2_{i2v2}) + \ldots + (Cn_{i_n v_n} * Dn_{i_n v_n})) + \sum_{x=1}^{n} (W_{v_x} * (M_1 + M_2 + \ldots + M_n))$$

Where, *C = Cost of treatment of ailment*

D = Type of ailment, i.e., illness/injury

W = Daily wages

M = Work days lost due to ailment

I = Type of agricultural practice adopted by farmer

v = Village

Observed material short-term and long-term ailments impacting farmers in this study are listed in Table 34.

A further analysis is conducted to test for correlation between TEV of health impact and agricultural practices adopted by farmers to test for the hypothesis that *CNF-practising farmers have lower human health impact*. Pearson correlation coefficient is used to test for a linear relationship, which is calculated as a number between -1 and 1 (with 1 being the strongest possible positive correlation and -1 being the strongest possible negative correlation). To evaluate how well the data rejects the null hypothesis, p-value (probability value) for the correlations is calculated. P-value is defined as the probability of obtaining results "as extreme" or "more extreme," given that the null hypothesis is true. In statistical hypothesis testing, the p-value is a probability measure of finding the observed, or more extreme, results, when the null hypothesis of a given statistical test is true. The p-value is used to quantify the statistical significance of the results of a hypothesis test. A common significance level

used is 0.05 (95% level of significance), which says that if the resulting p-value is equal to or less than 0.05, then there's strong evidence against the null hypothesis (Greenland, 2016).

A statistical test requires: 1) the derivation of a test statistic *t*, e.g., a t-value, for which the probability distribution is known, when the null hypothesis is true and some other distribution when the null hypothesis is false, and given that the set of model assumptions are true, e.g., independence of the model's error terms; and 2) a rejection rule, such that if the value of the test statistic is an extreme one that would rarely be encountered by chance under the null hypothesis, then the test provides evidence against the null hypothesis.

The formula for the test statistic t was calculated as:

$$t = {r\sqrt{n-2}}\Big/{\sqrt{1-r^2}}$$

Where, t = test statistic,

r = correlation statistic

n = no. of samples

In order to test the hypothesis *CNF-practising farmers have lower health impact,* we analyzed the correlation between prevalence of symptoms and agriculture practices.

5.2.2.2 Estimating household dietary score for farmers households

Dietary diversity is a qualitative measure of food consumption that reflects household access to a variety of foods and is also a proxy for the nutrient adequacy of individuals' diet. The household dietary diversity score (HDDS) is meant to reflect, in snapshot, the economic/social ability of a household to access a variety of foods (12 food groups are included). Studies have shown that an increase in dietary diversity is associated with socioeconomic status and household food security (household energy availability) (Hoddinot and Yohannes, 2002; Hatløy et al., 2000). The HDDS is meant to indicate household economic/social access to food, thus items that require household resources to obtain, such as condiments, sugar and sugary foods, and beverages, are included in the score. The HDDS is based on the food groups proposed by FANTA (Swindale and Bilinsky, 2006). The 12 food groups included are cereals; white tubers and roots; vegetables; fruits; meat, eggs, fish, and other seafood; legumes, nuts, and seeds; milk and milk products; oils and fats; sweets; spices; condiments and beverages. Dietary diversity scores are calculated by summing the number of food groups consumed in the household over the 24-hour recall period. Thus, the HDDS score can range from 0 to 12. The HDDS score is used to analyze the difference in food-plate diversity of different agriculture practices.

5.3 Results

5.3.1 Analysis of farm input-use by agricultural practice in study region

Based on survey data collected in the study area, the highest amount of chemical fertilizer is used in the Krishna-Godavari basin. This region has abundant water, and chemical-intensive farming practices are prevalent. Interestingly, the tribal hilly belt uses a higher amount of chemical fertilizer compared to the low-input rainfed regions of Andhra Pradesh (see Table 30).

Table 30: Average chemical fertilizer application by farmers across study area

	Krishna-Godavari basin	**Low-rainfed region**	**Tribal hilly belt**
Average chemical fertilizer applied (kg per ha)	456.38	107.05	140.38

Source: Compiled by author.

The majority of the survey respondents applied DAP, NPK in various proportions, or urea to their fields. Common methods of application are fertigation and broadcasting (see Table 31). In addition to method of application, Table 32 lists the pesticides commonly used by farmers in study area. Note that Monochrotophus was a commonly used highly hazardous pesticide, despite the pesticide being banned in India.

Table 31: List of fertilizers used by farmers in study area & corresponding method of application

Fertilizer name	**Count**	**Average quantity per ha (kg)**	**Average cost per ha (INR)**	**Common symptoms observed upon exposure**	**Method of application**
Fertisol	1	8.25	2,500	—	Application through irrigation water (fertigation)
Z-78	1	2.5	1,500	—	Broadcasting
NPK proportions	148	295	8,125	—	Broadcasting

Complex	76	157.5	—	—	Broadcasting
DAP	190	165	2,307.5	Skin rashes, burning eyes, headaches	Broadcasting
Gypsum	14	140	2,500	—	Broadcasting
Potash	124	217.5	4,175	—	Broadcasting
SSP	27	137.5	3,027.5	—	Broadcasting
UREA	197	317.98	2,843.5	Headache excessive sweating	Broadcasting
Zinc	19	830	3,167.5	—	Broadcasting
Ammonia	11	290	3,146	—	Broadcasting
HCL granules	32	25.6	3,905	—	Broadcasting
Humic acid	1	50	5,000	—	Application through irrigation water (fertigation)
Super	2	—	2,812.5	—	Broadcasting

Source: Compiled by author.

Table 32: List of hazardous pesticides used by farmers in study area

Pesticide name	Hazard classification		LD50 mg/kg	Regulatory status
Chlorpyrifos	Class II	Moderately hazardous	135	Chlorpyrifos was registered for 13 crops by CIBRC
Monochrotophos	Class Ib	Highly hazardous	14	Banned in India, high case fatality reported
Tricyclazole (Bhim)	Class II	Moderately hazardous	305	Subject to Rotterdam convention, high case fatality reported
Endosulfan	Class II	Moderately hazardous	80	Banned in India in 2011
Chlorantraniliprole (Dupont)	U	Unlikely to present acute hazard in normal use	> 5,000	Registered and commonly used pesticide
Bavistin	U	Unlikely to present acute hazard in normal use	>10,000	Registered and commonly used pesticide
Fame (Flubendiamide)	Class II	Moderately hazardous	>2,000	Registered and commonly used insecticide
Coragen (Chlorantiniliprole)	U	Unlikely to present acute hazard in normal use	> 5,000	Registered and commonly used pesticide
Karathane	Class III	Slightly hazardous	>2,000	Registered and commonly used fungicide
Cartap	Class II	Moderately hazardous	325	Registered and commonly used pesticide
Custodia	U	Unlikely to present acute hazard in normal use	>5,000	Registered and commonly used pesticide
Hexaconasole (Sofia)	Class III	Slightly hazardous	2,180	Registered and commonly used pesticide

Source: Compiled by author.

In comparison, Table 33 lists the inputs used by CNF practitioners as part of cultivation practices in the study area.

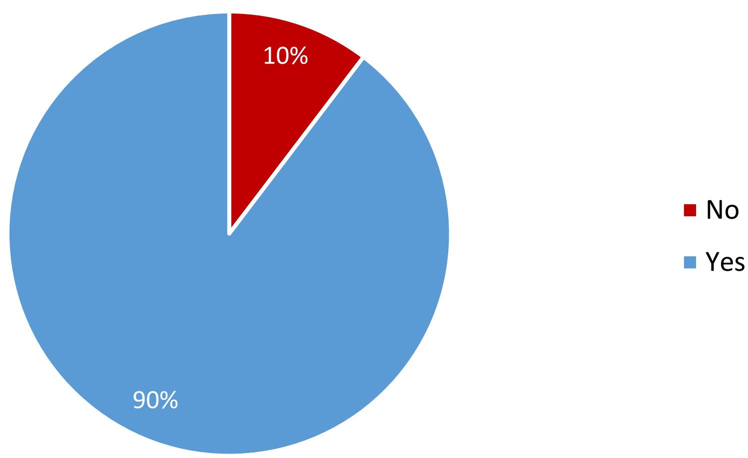
Table 33: List of inputs (natural concoctions) used by CNF farmers in study area & corresponding method of application; common symptoms are chosen based on the direct response collected from farmers & agricultural labourers via survey method

Input name	**Average quantity per ha**	**Average cost per ha (INR)**	**Common symptoms observed upon exposure**	**Method of application**
Beejamrutham	23.85 litres	67.5	Headache	Starter solutions
Drava jeevamrutham	20.45 litres	430	Headache, excessive sweating	Foliar application
Ghana jeevamrutham	945 kg	87.5	Headache	Broadcasting
Mulching	—	—	—	Placement
Sour buttermilk	70 litres	—	—	Foliar application
Neemastram (natural pesticide)	0.4 kg	802	—	Foliar application
Panchagavya	55 kg	702	—	Foliar application
Egg amino acids	85 kg	412	Headache, excessive sweating, vomiting	Foliar application

Source: Compiled by author.

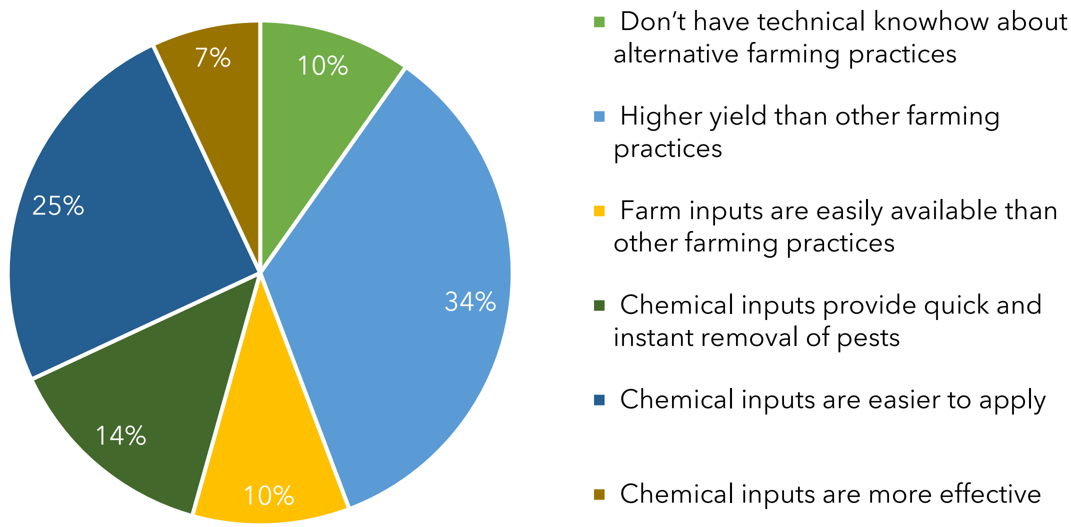
Improving farmers' access to information is key to avoiding the dangers associated with chemical inputs, and for reducing potential pollution to agricultural systems. In the current study sample, the majority of respondents (90%) were indeed aware of the harmful effects of the chemical inputs they use (see Figure 18). Despite this, 34% of respondents continue to use chemical inputs because they believe the inputs assist in producing a higher yield than other farming practices, and 14% believe that the inputs are more effective at pest removal. A quarter (25%) of respondents consider chemical inputs easier to apply (see Figure 19). Respondents noted that the information available to them was mainly from retailers and co-farmers.

Figure 18: Farmer awareness of the side effects associated with use of chemical inputs



Source: Compiled by author.

Figure 19: Reasons why farmers continue to use chemical inputs as part of agricultural practices

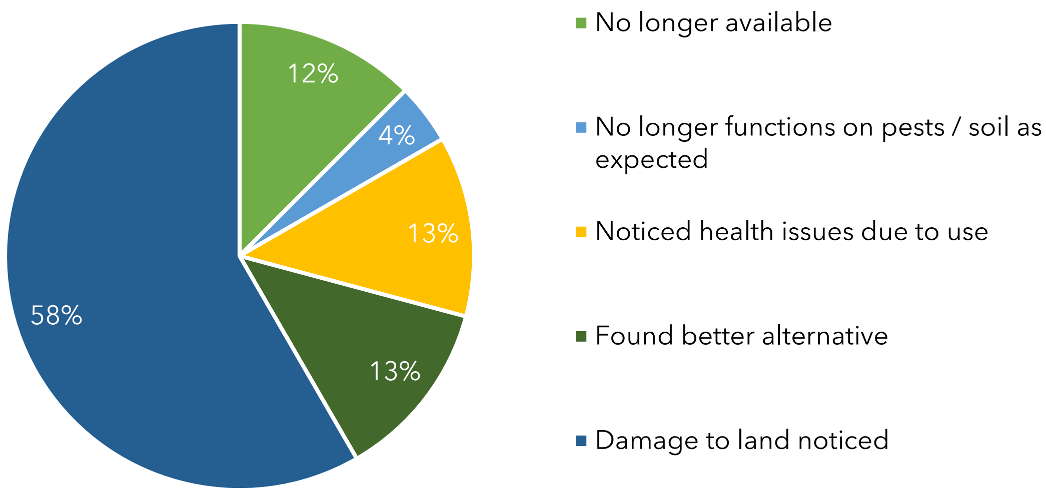


Source: Compiled by author.

As policy, the Indian standardized system of toxicity labels for pesticides uses a four-colour system (red, yellow, blue, green) to label containers with the toxicity class of the contents. The majority of respondents (74%) were aware of the toxicity codes used on pesticide bottles. In addition to this, pesticide bottles must also include safety instructions regarding storage, handling during preparation, application of the pesticides, and disposal of bottles. Only 53% of the respondents were provided with safety instructions to use the pesticides.

While 12% of farmers have stopped using certain chemical inputs due to unavailability (bans/restrictions on use) and reduced efficacy in managing pests (4%); 13% of farmers have stopped use of such chemicals due to observed side effects such as eye irritation, headache, dizziness, breathing difficulty, skin rashes, etc. The majority of farmers (58%) have stopped due to observed damages to land, including changes to soil quality and production quality and quantity after using certain chemical inputs. The use of chemical inputs stopped/intended to stop include Chrochrum, DAP, Complex, Endosulfan, Fortey Crystal, and Monochrotophus.

Figure 20: Reason behind ceasing the use of certain chemical inputs by farmers



Source: Compiled by author.

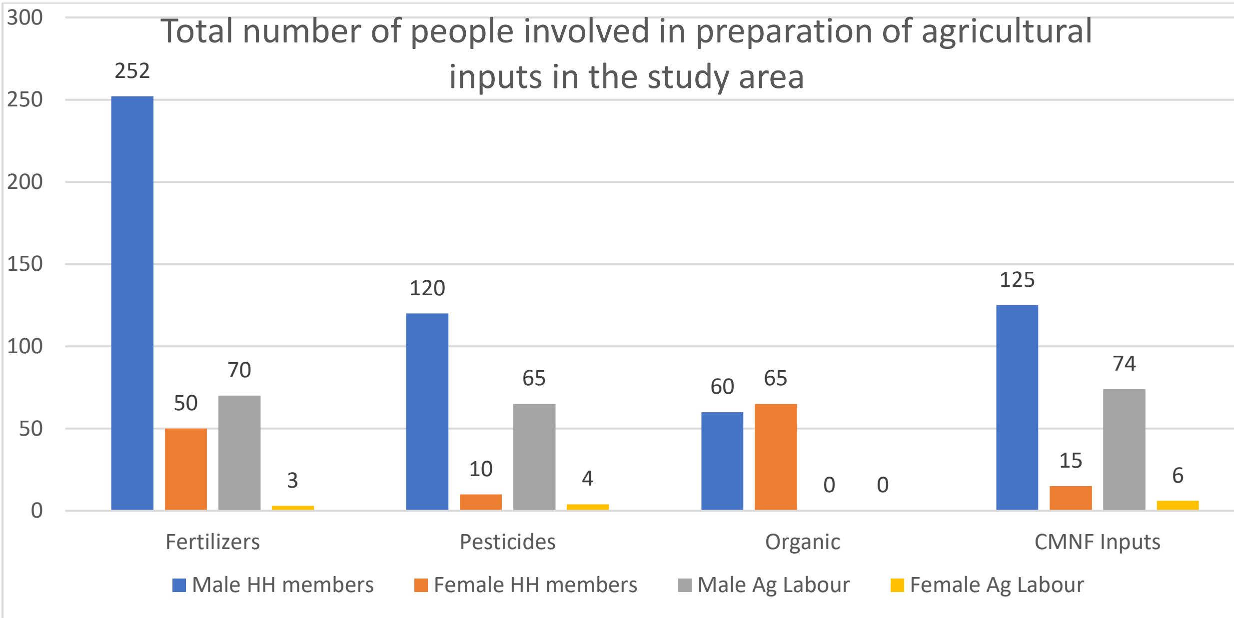
Almost half (49%) of non-CNF farmers surveyed across the three agroecological regions in Andhra Pradesh were aware of CNF practices.

5.3.2 Procurement, storage, & application practices for chemical, organic, & CNF inputs by farmers

Surveyed respondents (see Figure 21 and Figure 22) indicated that chemical fertilizer preparation is mostly done by male household members, while the chemical fertilizer application is done by male household members and/or hired male agriculture labourers.

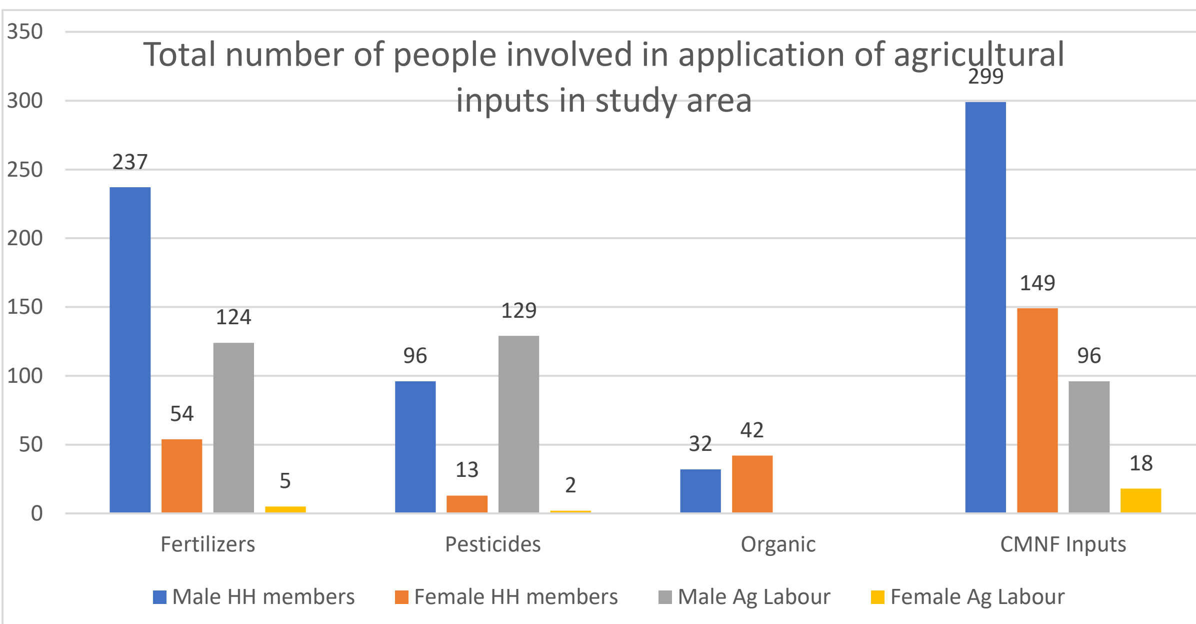
In contrast, women household members were mostly involved in the preparation and application of organic inputs, which commonly include cow dung, compost, and neem powder.

Figure 21: Total number of people involved in preparation of agricultural inputs in study area



Source: Compiled by author.

Figure 22: Total number of people involved in application of agricultural inputs in study area

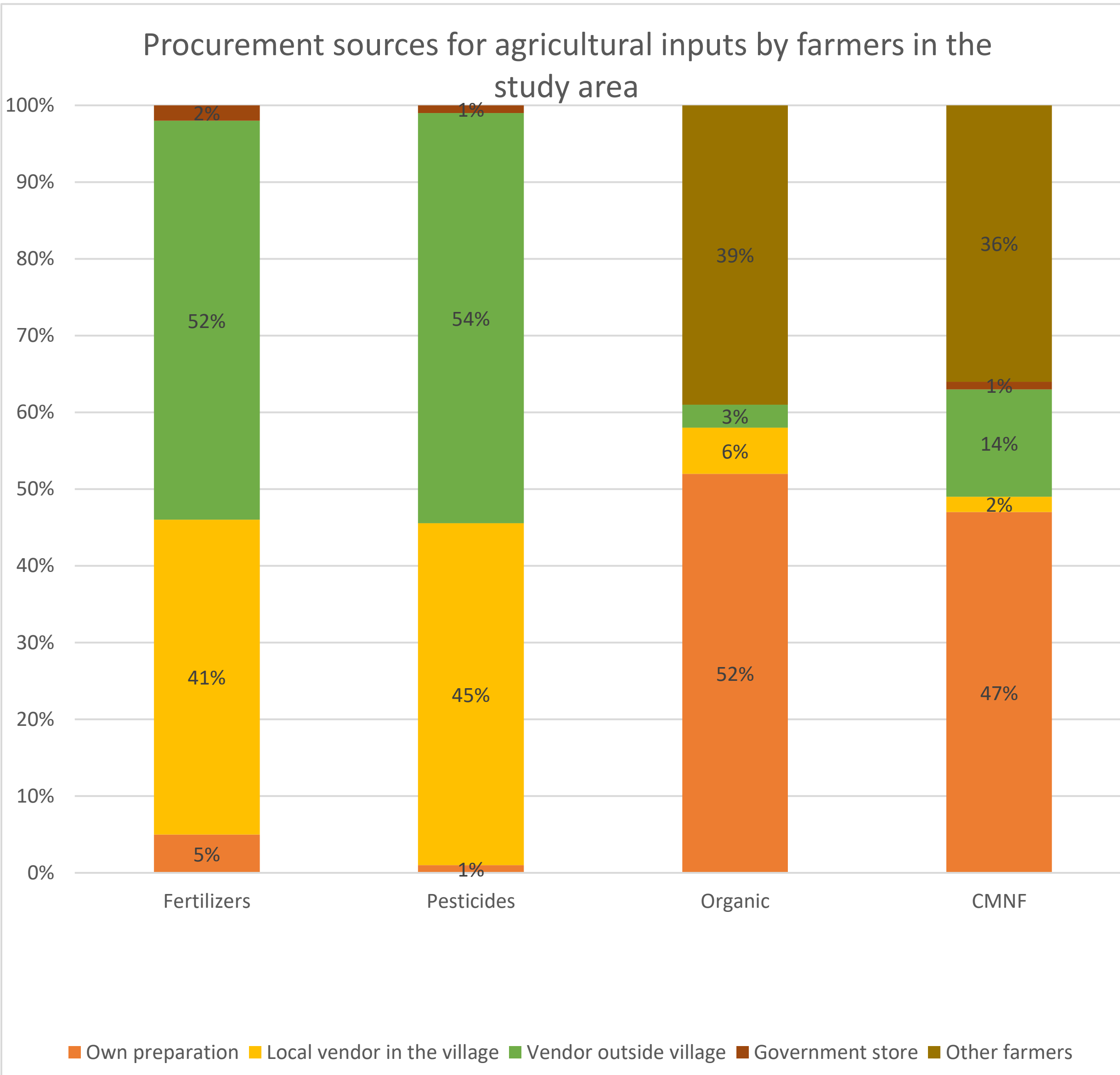


Source: Compiled by author.

The farmers surveyed who use chemical inputs (52% for fertilizers and 54% for pesticides) primarily procure the chemical inputs from vendors outside the villages. Most organic and CNF farmers prepare their inputs either at home (52% and 47%, respectively) or purchase them from other farmers in the village (39% and 36%, respectively).

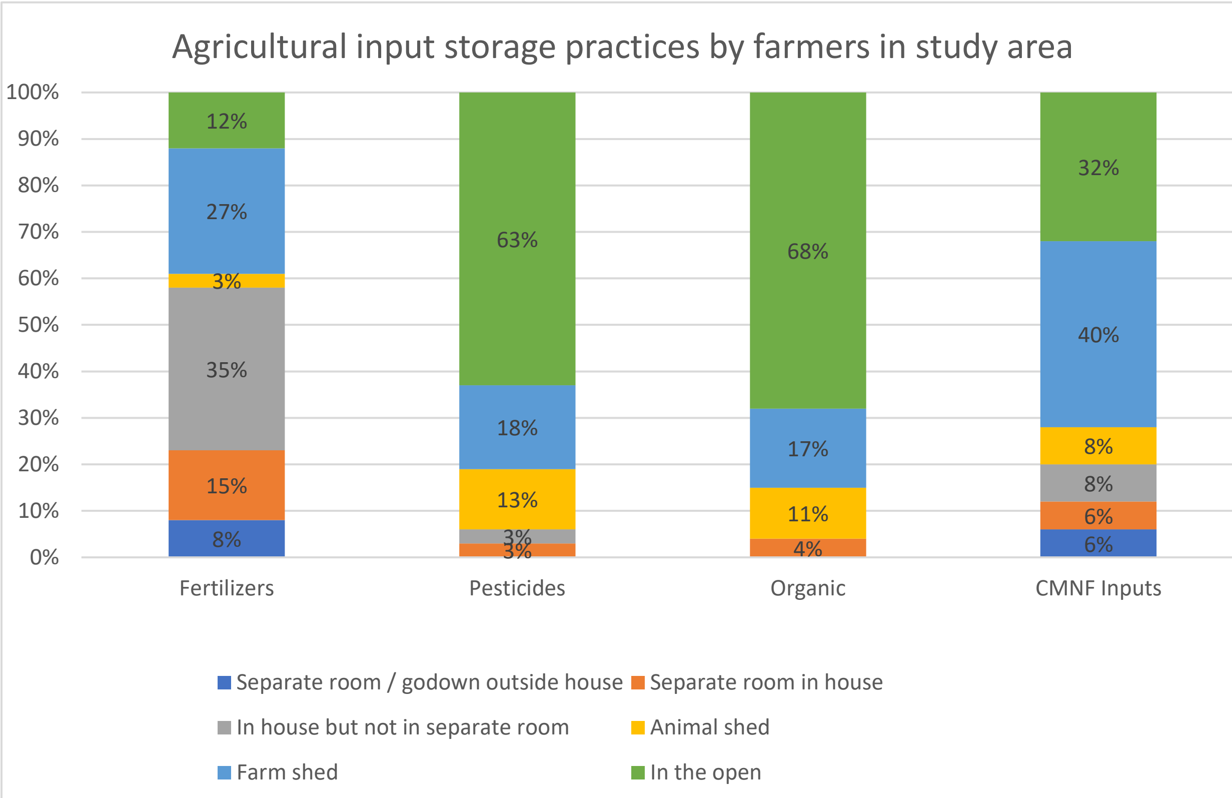
Figure 23 provides a detailed breakdown of the sources from which farmers procure their agricultural inputs.

Figure 23: Procurement sources for agricultural inputs by farmers in study area



Source: Compiled by author.

Figure 24: Agricultural input storage practices by farmers in study area



Source: Compiled by author.

Chemical fertilizers require storage in dry, well-drained, and smooth surfaces. Certain farm inputs, such as calcium nitrate– and magnesium sulphate–based fertilizers, and urea and ammonium nitrate, must be stored in separate areas to avoid risks. In fact, most fertilizer manufacturers recommend storage of their products in separate rooms away from living areas. Despite this, 35% of farmer respondents who use chemicals indicated they store the chemical fertilizer in their house and not in a separate room, whereas 12% of respondents store it in the open. It is also recommended that pesticides be stored away from the house premises as well as away from direct sunlight and rain. The majority of farmer respondents who use chemicals (63%) stored pesticides in the open. Alternatively, 40% of CNF respondents stored the CNF inputs in their farm sheds, and 32% stored it in the open. Organic inputs are mostly stored in the open (68%) or in the animal/farm shed.

Recommendations for the use of personal protective equipment (PPE) and precautionary practices to avoid direct contact with chemical inputs during preparation and application are well documented but not widely practised. This is evidenced by the fact that 53% and 47% of the respondents practising chemical-intensive agriculture do not take any precautions while preparing the fertilizers and pesticides, respectively (see Figure 24). Almost 20% of farmers do not use any precautions during the application of these chemical inputs, and the majority who do (72%) merely use face and

eye masks (Figure 25: ***Precautions* taken during preparation of agricultural input by farmers in study area**

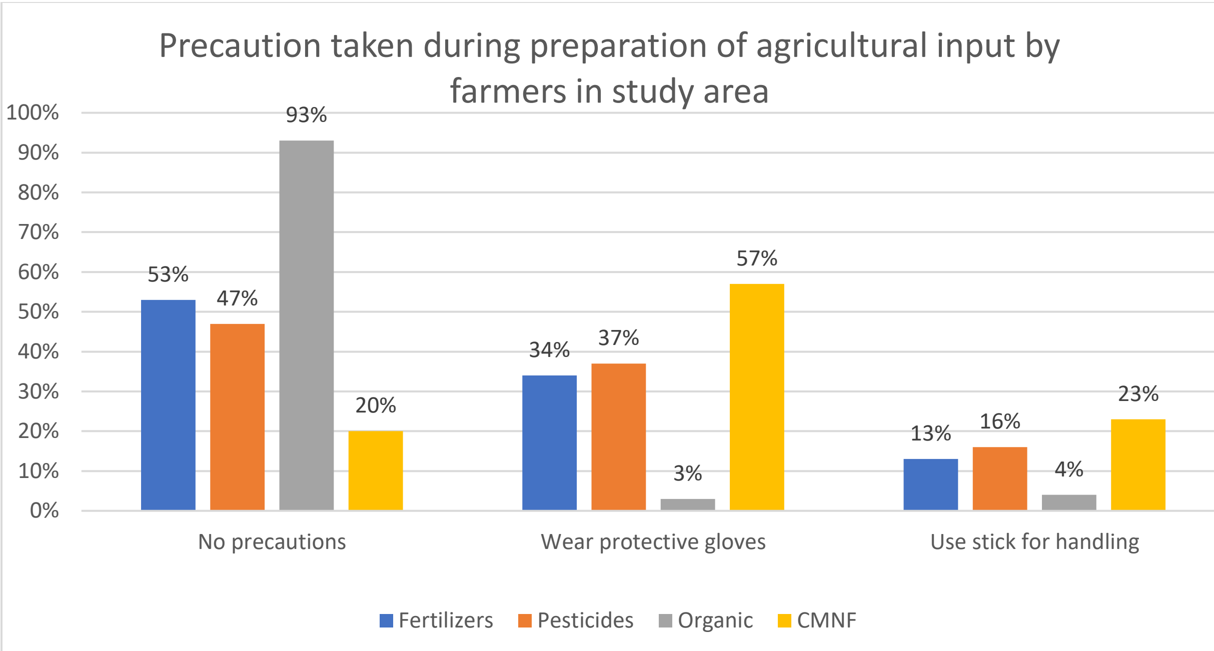
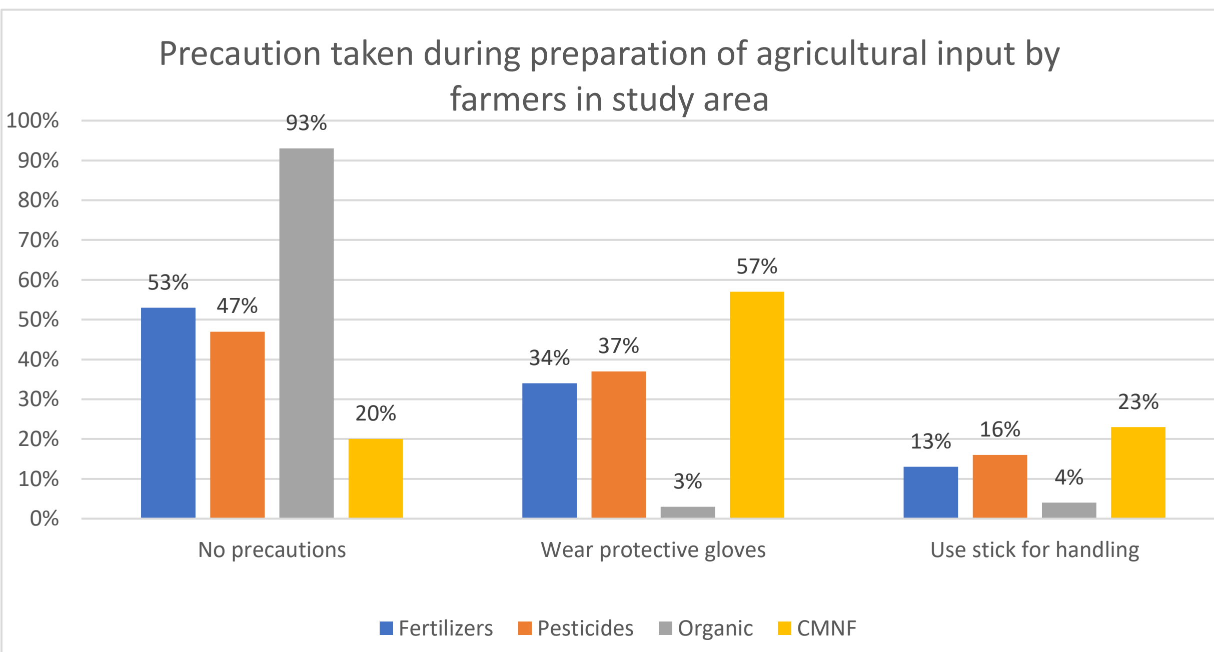


Figure 25: Precautions taken during preparation of agricultural input by farmers in study area



Source: Compiled by author.

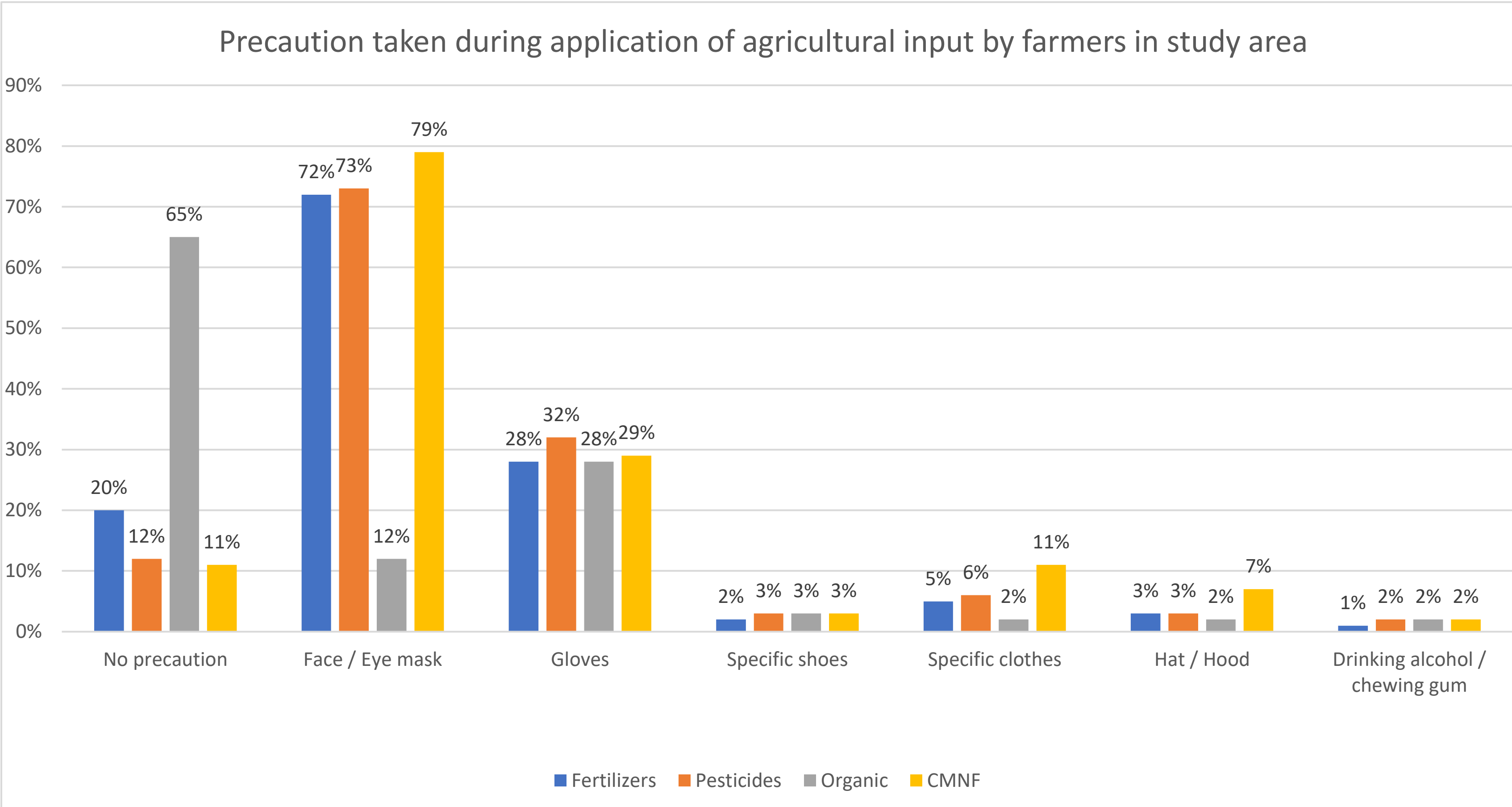
The majority of tribal farmers do not take any precautions during the preparation and application of organic inputs (93% and 65%, respectively), whereas only 20% and 11% of CNF farmers do not practice any precautions while preparing or applying CNF inputs, respectively.

Basic protective measures during and after pesticide application can be effective in reducing the risk to farmer's health. Common precautions taken after application of agricultural inputs are: washing hands and feet with soap; bathing; changing clothes; and washing clothes used during application.

Figure 27 provides a detailed breakdown of the post-application practices followed by farmers in the study area.

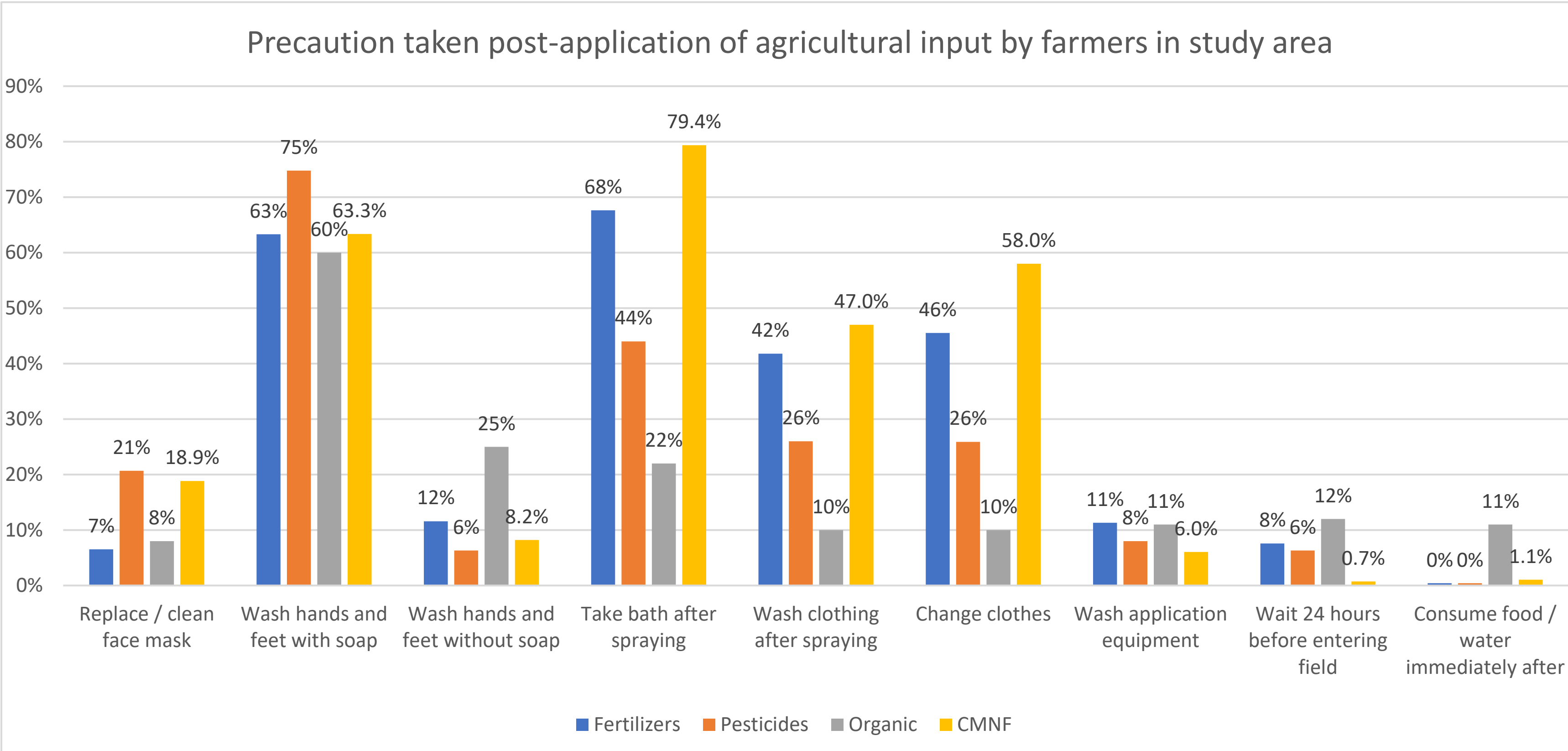
The survey showed that the application of CNF inputs required more labour compared to the application of chemical inputs (i.e., is more labour intensive). Also, when it came to chemical pesticide application, farmers preferred to rely on agricultural labourers.

Figure 26: Precaution taken during application of agricultural input by farmers in study area



Source: Compiled by author.

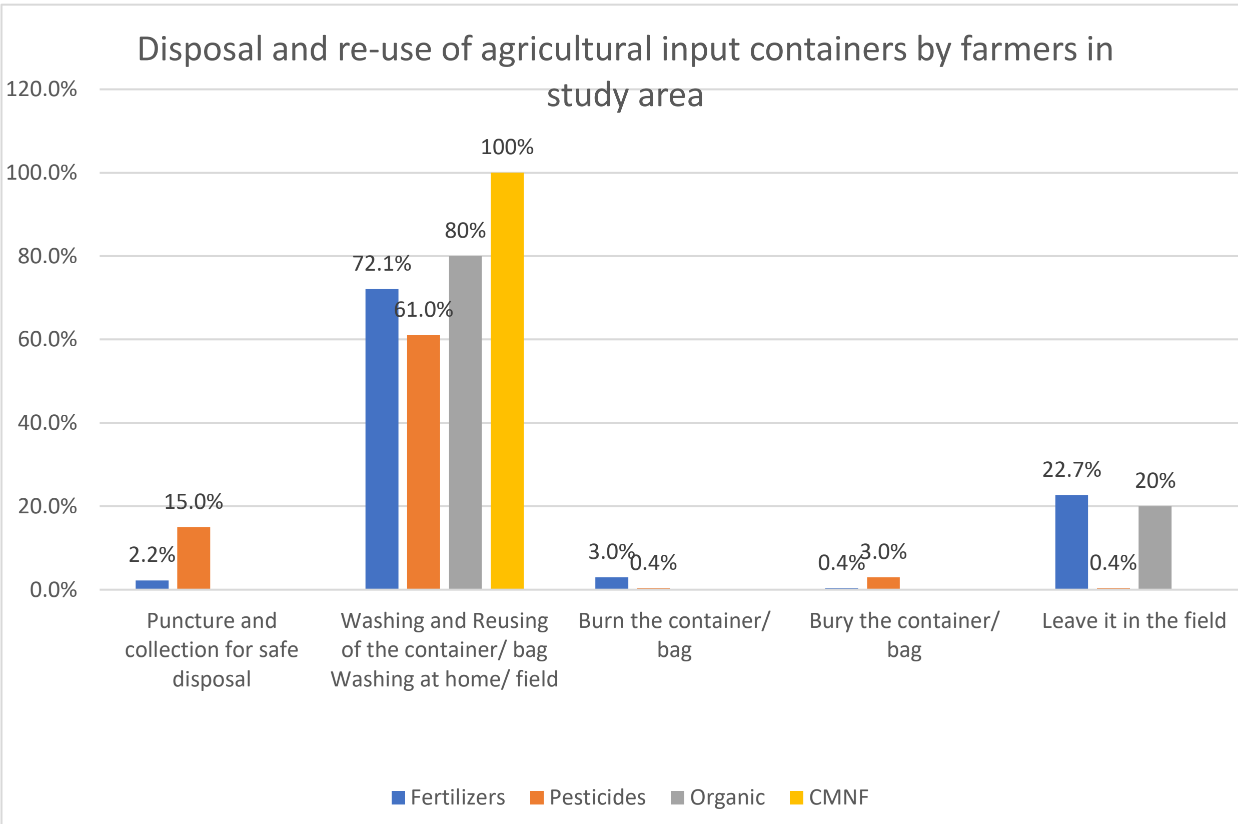
Figure 27: Precaution taken post-application of agricultural input by farmers in study area



Source: Compiled by author.

A concerning practice observed during the study was the re-use of containers (mostly bottles and bags) in which pesticides are stored. Unsafe disposal of both unwanted pesticides and empty pesticide containers can put the general population at higher risk of exposure. The majority of the respondents wash and reuse the container/bag at home or in the field. Very few respondents safely dispose of the bottles of fertilizers and pesticide (2% and 15%, respectively) (see Figure 28).

Figure 28: Disposal and re-use of agricultural input containers by farmers in study area



Source: Compiled by author.

5.3.3 Human health impacts from short-term & long-term exposure to agricultural inputs for farmers in study area

Based on a survey of 280 respondents, both non-CNF and CNF practitioners experienced significant losses in productivity (via loss of work days) due to exposure to agricultural inputs. The total estimated economic value of losses was based on income losses and treatment costs incurred by farmer households.

Given the prevalence of data gaps – and after elimination of outliers[2] – in occurrences of exposure symptoms and incurred health costs, we have extrapolated data covering all sample farmer households. The current assessment shows that chemical-intensive agricultural practices do have a borderline correlation to impacts on human health (via short-term symptoms) and health costs incurred by farmers/farm labourers (see Table 36) as correlated to the marginal increase of exposure to chemical inputs.[3]

Table 35 demonstrates that chemical-intensive practitioners are likely to suffer higher economic losses as result of higher health costs (treatment of symptoms) and productivity loss (work days lost due to illness). The range of economic losses is spread between INR 6,210 for tribal organic farming to INR 313,740 for farmers practising chemical-intensive farming.[4] Chemical-intensive practitioners lost an average of 189 work days, as opposed to an average of 121 work days lost by CNF practitioners (despite CNF being more labour intensive). Also, farmers practising chemical-intensive farming reported higher incidences of symptoms associated with exposure, including headaches, burning eyes, and skin rashes (see Figure 14).

Estimating the correlation between long-term exposure to agricultural inputs and its impact on farmer health was not feasible in this study given the small sample size and lack of longitudinal/timeseries data. Also, it is worth noting that current CNF practitioners were previously chemical-intensive practitioners before converting to CNF – a contributing factor given the long-term impacts on human health from exposure to chemicals at either a specific point in time or over time.

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[2] Outliers relate to the prevalence of similar symptoms described by survey respondents that were attributable to other pre-existing ailments.

[3] In addition to statistical analysis, this can be concluded on the basis of on-ground observation/anecdotal evidence that the symptoms described by respondents were post-handling of said chemical inputs based on prevalent practices.

[4] Average losses are calculated as the average cost per practitioner. The total number of respondents providing complete and accurate responses for tribal farmers was very low (5) so statistical significance is low. These can be analyzed from an anecdotal perspective to get an overview of the health impacts experienced by tribal organic farmers.

General observation of the data (see Table 37) does indicate that chemical-intensive practitioners have higher reported occurrence of ailments compared to their CNF counterparts.

Table 34: Impact of agricultural management practices on farmer health

Type of farming	Number of survey responses	Agricultural input management practices	Prevalence of symptoms	Work days lost	Total economic loss (INR)
Chemical-intensive farming	280	No usage of PPE	Headache, excessive sweating, burning eyes, runny nose, skin rashes, twitching eyelids, dizziness, nausea, vomiting, shortness of breath, excessive salivation	189	INR 313,740
		Improper storage of inputs	Headache, burning eyes, runny nose, skin rashes, twitching eyelids, dizziness, nausea		
		No post-application precaution taken	Headache, excessive sweating, burning eyes, runny nose, skin rashes, twitching eyelids, dizziness, nausea, vomiting, shortness of breath, seizure, muscle cramp		
Low-rainfed farming	21	No usage of PPE	Headache, excessive sweating, burning eyes, runny nose, skin rashes	11	INR 6,631
		Improper storage of inputs	Headache, excessive sweating, burning eyes		
		No post-application precaution taken	Headache, excessive sweating, nausea, vomiting		
	5	No usage of PPE	—	10	INR 6,210

Tribal organic farming		Improper storage of inputs	—		
		No post-application precaution taken	—		
CNF farming	282	No usage of PPE	Headache, vomiting, nausea, skin rashes, excessive sweating	121	INR 231,522
		Improper storage of inputs	Headache, vomiting, nausea, skin rashes, burning eyes		
		No post-application precaution taken	Nausea, vomiting, headache, dizziness		

Source: Compiled by author.

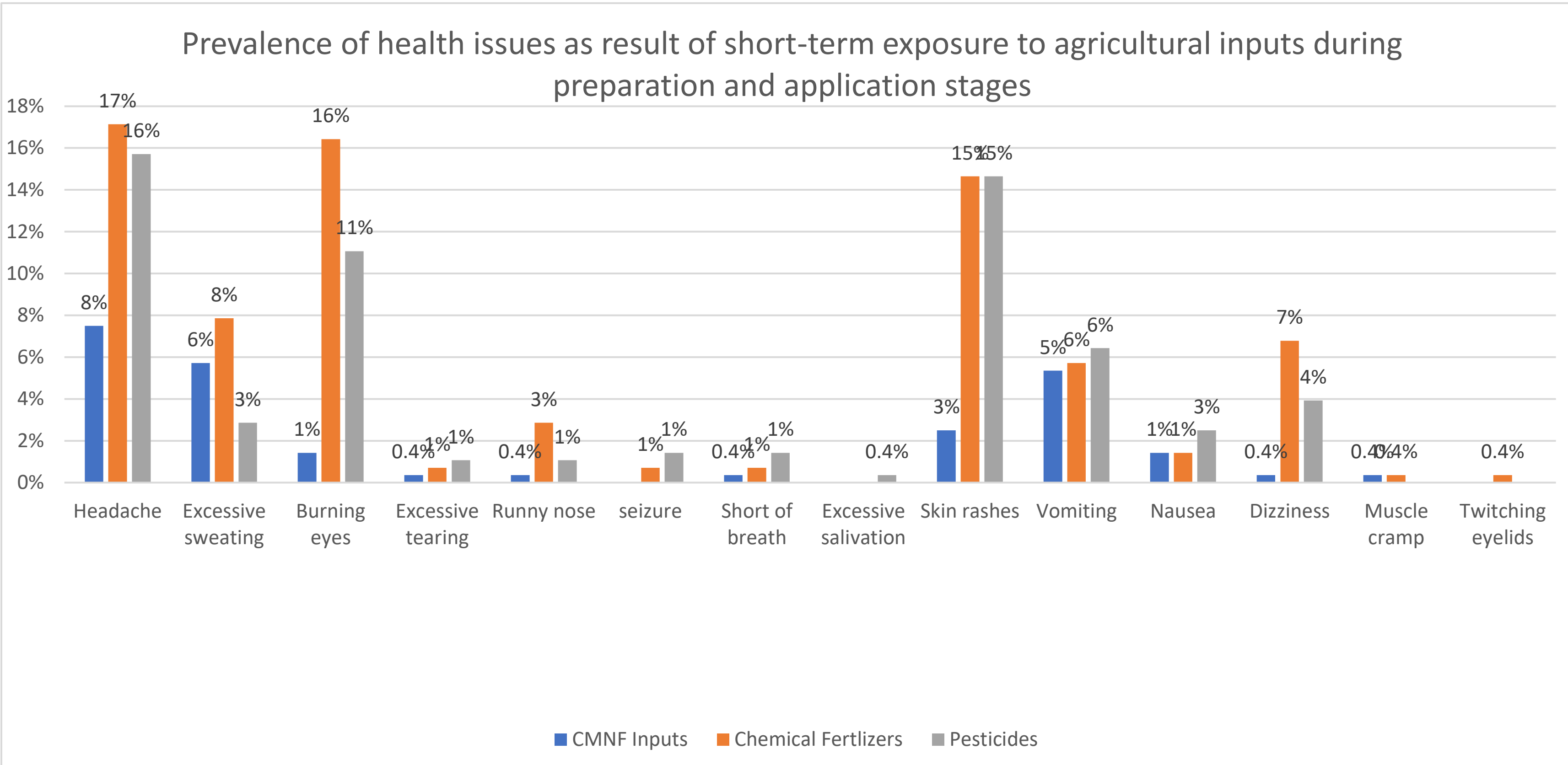
Table 35: Correlation between agricultural practices & prevalence of short-term symptoms & health costs

Type of farming	**(A) Correlation between prevalence of symptoms & agri-practices (P-Value)**	**Average economic loss (INR)**	**Standard deviation (INR)**	**(B) Correlation between health cost & agri-practices (P-Value)**	**Comment**
Chemical-intensive farming	0.072	INR 1,120	INR 1,735	0.071	Borderline significance for both A and B
Low-rainfed farming	0.11	INR 1,100	INR 354	0.62	No statistically significant correlation for both A and B
Tribal organic farming	0.13	INR 621	INR 7,651	0.79	Low sample size to conduct a correlation analysis. No statistically significant correlation for both A and B
CNF farming	0.08	INR 821	INR 502	0.74	Trending toward significance for A and no statistically significant correlation for B

Note: P-value ≤ 0.05 is statistically significant.

Source: Compiled by author.

Figure 29: Prevalence of health issues as result of short-term exposure to agricultural inputs during preparation & application stages



Source: Compiled by author.

Table 36: Long-term health impacts on farmer households in study area

		Ailments										
		Hypertension	**Cholesterol**	**Asthma**	**Rheumatoid arthritis**	**Tuberculosis**	**Kidney disorders**	**Back pain**	**Joint pain**	**Thyroid**	**Breast cancer**	**Diabetes**
Chemical-intensive farming	No. of individuals	35	1	2	4	2	3	14	23	2	2	4
	Average annual household expenditure on treatment (INR)	16,330	10,000	13,500	3,100	5,000	40,000	23,322	5,948	21,000	17,500	6,200
	Average productive days lost	8	0	4		12	10	19	30	15	120	0
	Average productivity loss (INR)	3,680	0	1,610	0	5,520	4,600	8,740	13,800	6,900	55,200	0
	Average cost of illness for farmer household (INR)	20,010	10,000	15,110	3,100	10,520	44,600	32,062	19,748	27,900	72,700	6,200
Tribal organic	No. of individuals	1	0	0	0	0	0	0	0	0	0	0
	Average annual household	1,00,000	0	0	0	0	0	0	0	0	0	0

	expenditure on treatment (INR)											
	Average productive days lost	10	0	0	0	0	0	0	0	0	0	0
	Average productivity loss (INR)	4,600	0	0	0	0	0	0	0	0	0	0
	Average cost of illness for farmer household (INR)	104,600	0	0	0	0	0	0	0	0	0	0
Low-rainfed farming	No. of individuals	0	2	0	0	0	0	0	0	0	0	0
	Average annual household expenditure on treatment (INR)	0	4,700	0	0	0	0	0	0	0	0	0
	Average productive days lost	0	1	0	0	0	0	0	0	0	0	0
	Average productivity loss (INR)	0	460	0	0	0	0	0	0	0	0	0
	Average cost of illness for farmer household (INR)	0	5,160	0	0	0	0	0	0	0	0	0

APCNF Practitioners	No. of individuals	18	0	6	11	0	5	25	12	5	0	12
	Average annual household expenditure on treatment (INR)	5,308	0	9,960	9,785	0	1,06,250	11,000	8,133	4,945	0	7,800
	Average productive days lost	11	0	25	38	0	42	25	16	7	0	
	Average productivity loss (INR)	5,060	0	11,500	17,480	0	19,320	11,500	7,360	3,220	0	0
	Average cost of illness for farmer household (INR)	10,368	0	21,460	27,265	0	125,570	22,500	15,493	8,165	0	7,800

Source: Compiled by author.

5.3.4 Impact of agricultural practices on household diets of farmers

5.3.4.1 Average food-plate diversity of farmer households in study region

Diets across India vary widely from region to region, depending on the availability of food and cultural practices. Table 37 illustrates an average household diet in Andhra Pradesh. With development in agricultural practices, the availability of inexpensive staple cereal crops has increased, which has successfully reduced hunger (Shankar S, 2017) but at the expense of diet diversity and by displacing local foods such as legumes, nuts, milk, vegetables, and fruits. Studies have demonstrated that a 10% increase in agricultural crop diversity results in a 1.8 to 2.4% increase in dietary diversity (Dillion et al., 2014).

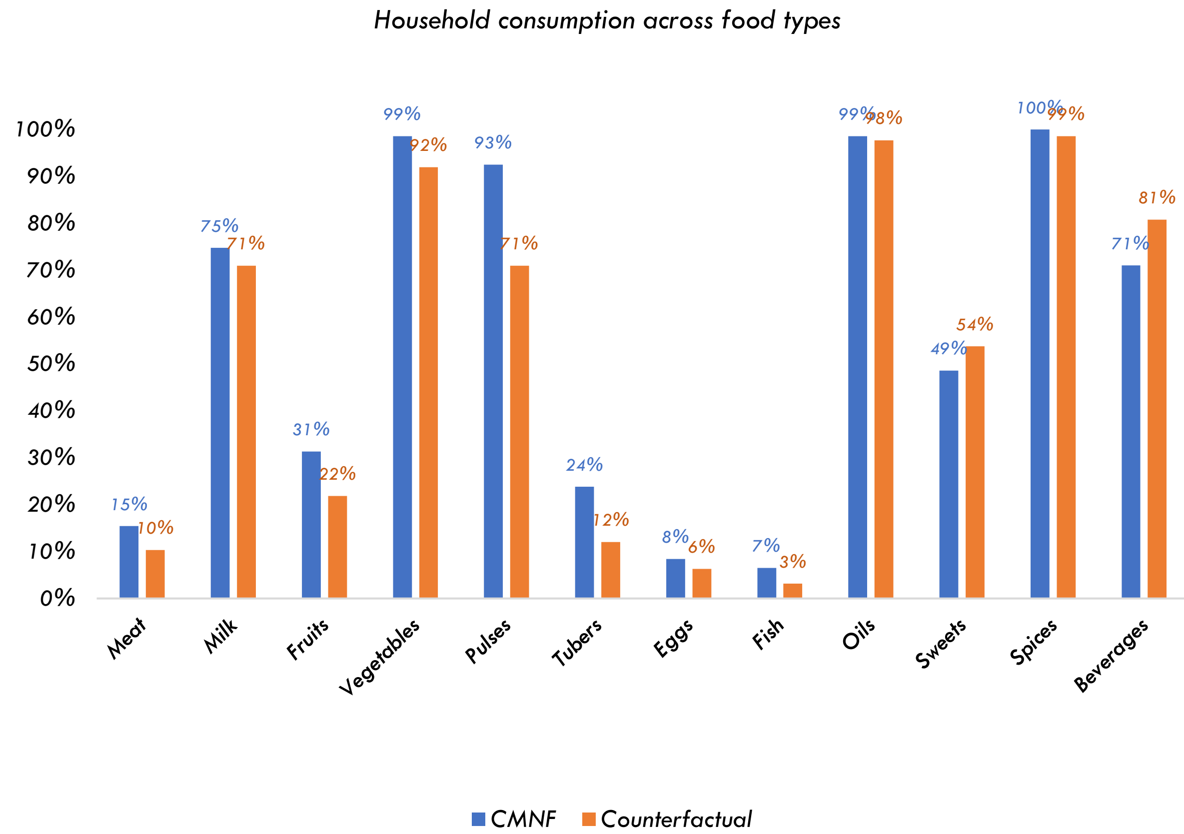
Table 37: Food items & macronutrients percentage for an average Andhra diet

Macronutrient type	**Percentage**	**Common food items consumed**
Protein	8%	Eggs, chicken, dosa, idli
Cereals	59%	Rice, chapati
Pulses	5%	Bengal gram
Dairy	20%	Cow's milk
Fruits and vegetables	8%	Banana, green leafy vegetables

Source: Shankar, S., and Rao B., 2019.

Our study clearly demonstrates that that CNF households consume more foods across all food types compared to chemical-intensive, tribal organic, and low-rainfed agriculture practising households (see Figure 30). Also, note that the average diet of farmers covered in study contained more macronutrient diversity than the average Andhra food plate, indicating that the farmer households have access to a wider range of food crops.

Figure 30: Household food consumption pattern in study area



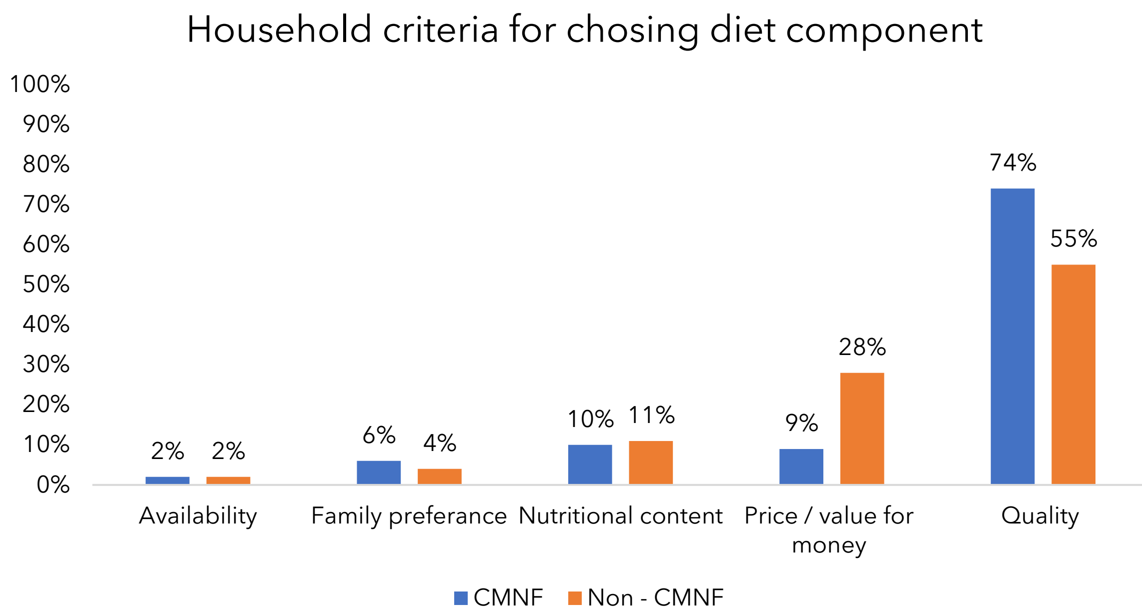
Source: Compiled by author.

5.3.4.2 Key factors determining the diets of farmer households in study region

Figure 31 illustrates the factors that determine diet in the study villages. When deciding family diet, farmers practising CNF consider quality their biggest driving factor (74%), followed by nutritional content (10%) and price/value for money (9%). While non-CNF household diets are also driven by quality (55%), prices play a much larger role (28%) when deciding family diet.

Additionally, 95% of the study's respondents were aware of the benefits of a healthy diet, and 80% respondents believed that organically grown vegetables are much heathier. In fact, almost half of the respondents (49%) from CNF villages have their own kitchen gardens to grow fruits and vegetables or purchase them from other CNF and organic farmers. The other half (49.5%) procure their fruits and vegetables from local and outside vendors. Only a very small fraction (1.5%) consumes fruits and vegetables grown using chemical-intensive practices. In counterfactual villages, most respondents (87%) purchase fruits and vegetables from local and outside vendors, 10% procure them from local CNF and organic farmers, and 2.5% grow them using chemical-intensive practices. Food grains are procured from the Public Distribution System in both CNF and counterfactual villages.

Figure 31: Key factors determining household diet for farmers in study



Source: Compiled by author.

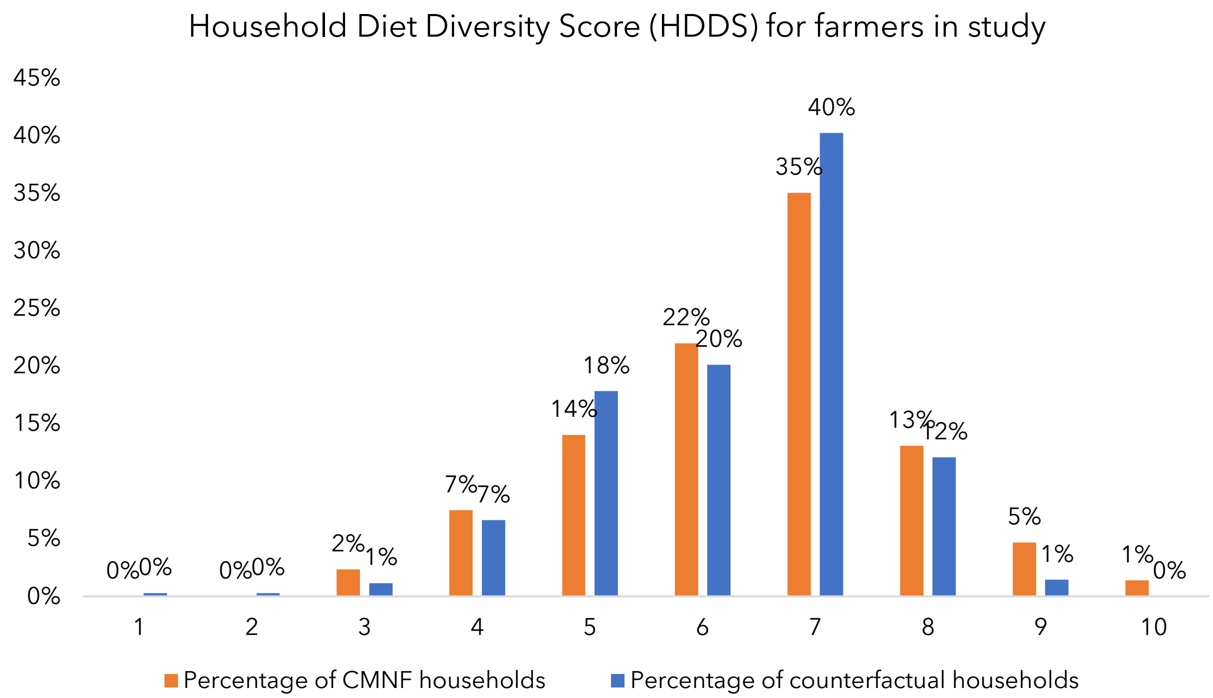
5.3.4.3 Household dietary diversity score of farmer households in study

The household dietary diversity score (HDDS) is meant to reflect, in snapshot form, the economic/social ability of a household to access a variety of foods. Studies have shown that an increase in dietary diversity is associated with improved socioeconomic status and household food security (household energy availability) (Hoddinott, 2002; Hatløy, 2000).

The 12 food groups included in our HDDS are cereals, white tubers and roots, vegetables, fruits, meat, eggs, fish and other seafood, legumes, nuts and seeds, milk and milk products, oils and fats, sweets, spices, condiments, and beverages. In this study, we calculate the HDDS by summing the number of food groups consumed in the household or by the individual respondent over the 24-hour recall period. Thus, the HDDS can range from 0 to 12, depending on the dietary practices of respondent households.

The HDDS of respondent farmer households are listed in Figure 32. It clearly shows that the majority of the households (both CNF and counterfactual) score in the 6 to 7 range. Interestingly, no respondents from CNF villages score below 3. None of the respondents, neither CNF nor counterfactual, score above 10.

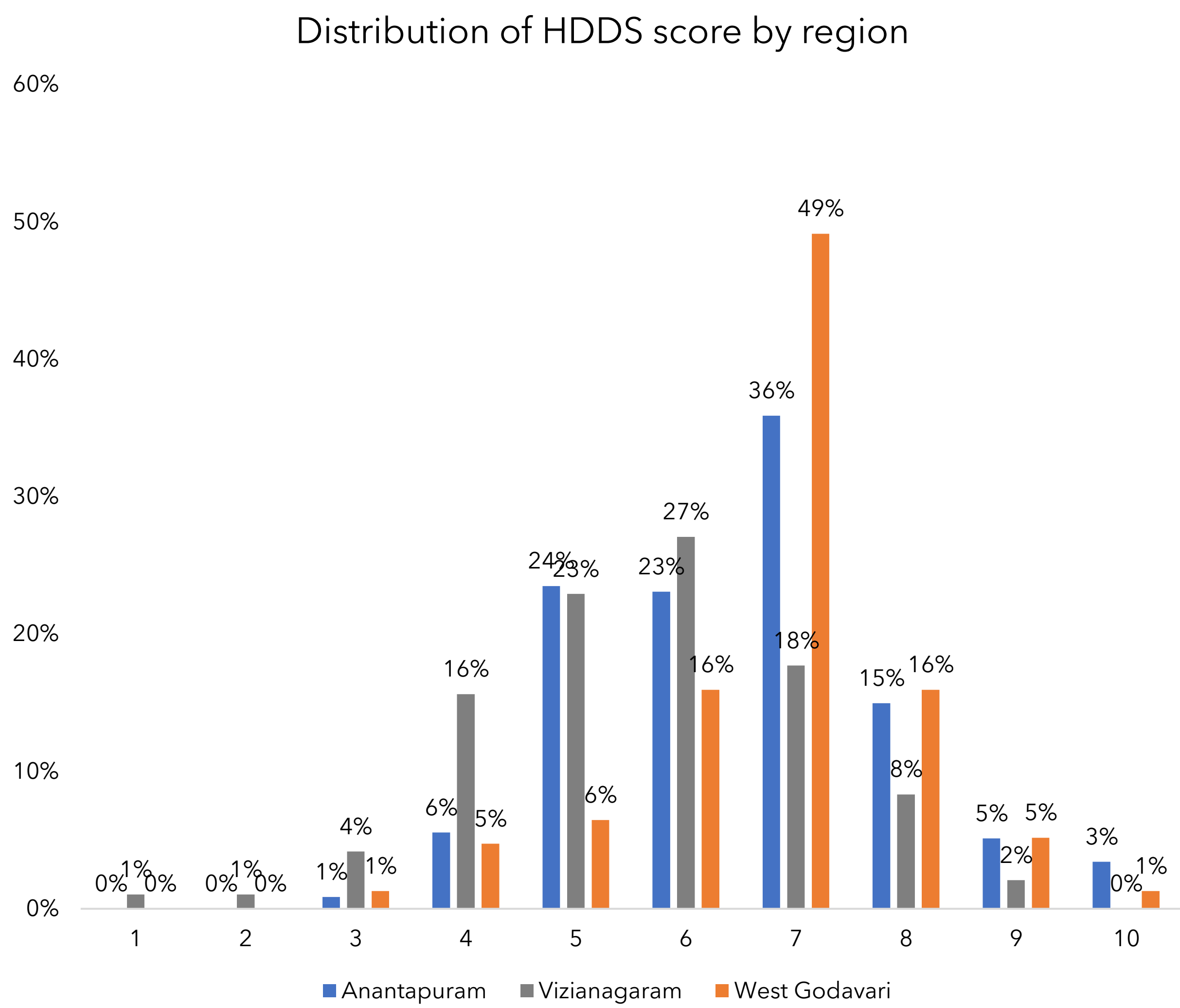
Figure 32: Household diet diversity score (HDDS) for farmers in study



Source: Compiled by author.

Based on respondent data, it is clear that CNF households consumed diets containing milk, fruits, vegetables, pulses, oils, sweets, spices, cereals, and meat. Whereas counterfactual households predominantly consumed cereals, vegetables, tubers, sweets, pulses, and oils. CNF farmer households consume higher amounts of fruits and vegetables, which is not surprising given the presence of multi-cropping practices and kitchen gardens in such households. Despite having higher incomes, counterfactual farmer households (see Figure 30) consume less protein (pulses, milk, meat, eggs, fish) than CNF households. Increases in farmer incomes do not necessarily translate into increased nutrient consumption, likely due to strong preferences for a particular type of diet (i.e., a vegetarian diet).

Figure 33: Distribution of HDDS score by region



Source: Compiled by author.

At a regional level, the HDDS demonstrates that farmer households in the tribal-dominated hilly regions (i.e., Vizianagaram District) score an average of 6.65. Farmer households in low-rainfed areas (i.e., Ananthapuram District) score an average of 7.82. Farmer households in West Godavari score an average of 7.62.

5.4 Conclusion & policy implications

Given the low response rate of tribal and semi-arid farmers, this study is most reliable in comparing CNF and chemical-intensive agricultural management practices and their impacts on on-farm human health. The study finds evidence to support the hypothesis that *CNF farming has lower human health impacts compared to chemical-intensive farming.*

The analysis demonstrates that the use of chemical inputs (such as pesticides and fertilizers) leads to higher incidences of short-term exposure and symptoms such as headache, sweating, nausea, and burning of eyes. This, in turn, leads to material health costs and productivity losses, which are a negative externality for farmers and unaccounted in traditional market-based crop-pricing models. Table 35 and Table 36 clearly show that CNF farmers have both, lower total economic impact of on-farm health ailments (INR 2,31,522) as well as lower average economic losses per farmer (INR 821) compared to chemical-intensive farming practices (INR 3,13,740 and INR 1,120, respectively). In all cases, we find that inadequate practices such as not using personal protective equipment (PPE), improper storage, and not taking necessary precautions after application are key factors determining incidences of exposure, leading to health impacts for farmers/farm labour. With respect to the long-term health impacts on farmers and farmer households, a larger data set and timeseries data is needed to analyze the links between occurrence of material ailments (including cancer) for non-CNF and CNF practitioners going forward.

The HDDS provides some interesting insights. CNF farmer households do tend to consume more varied diets compared to their counterparts (see Figure 31), but despite this no household (CNF or counterfactual) consumes a richer diet (comprising of all 12 food groups covered in HDDS study). Farmer households in Andhra Pradesh, even those with higher-than-average incomes, do not consume enough fruits and non-dairy protein (see Figure 30). This points to cultural preferences and embedded food habits as the major causes for the limited diets.

In the absence of holistic measures of the true cost of food – i.e., the environmental, human, social, and financial cost – stakeholders cannot make informed choices. What ends up being adopted at scale is an unsustainable agri-food ecosystem dependent on monocropping and extensive energy and chemical-input subsidies, which generates significant negative environmental and human health externalities. Our study brings evidence that there are alternative practices, such as CNF, that have a much lower on-farm human health cost while simultaneously enhancing the accessibility of rural households to more diverse foods and diets.

6 Conclusion

Harpinder Sandhu, Federation University Australia, Victoria, Australia

Pavan Sukhdev, GIST Impact Switzerland SA

This study compares CNF against three counterfactuals, i.e., the chosen three types of prevalent production systems in the region (low-input rainfed, chemical, and low-input tribal farming systems in the semi-arid, Godavari delta, and tribal hilly areas, respectively) for economic dimensions, social capital, and health impacts. Chapter 3 draws upon two studies, crop-cutting experiments, and household surveys to demonstrate that CNF increases crop yields, reduces costs of production (low fertilizer and pesticide input-use, lower costs of seeds and machinery), and thus increases net income per hectare (ha). Crucially, in terms of yields, gross income, and net income, CNF performs equally or better than all other types of farming, including the chemical-intensive farming in the delta region. The largest improvement in yields and net income was measured in the semi-arid areas, while in the delta area we observed comparable yields but a decrease of costs. CNF also increases diversity on farms (number of crops) and demand for rural labour. There are additional benefits from reduced negative impacts of pesticide use. Farmer testimony indicates that CNF adoption also results in changes to diet, health, and housing.

A key component of the sustained scaling of CNF in Andhra Pradesh has been the layering of initiatives and diversity of adoption pathways, allowing for experience to build. The RySS acts as the core agency responsible for all aspects of the roll-out of CNF, and its work is supported by funding from the central and state government, as well as funding from private philanthropy (Aziz Premji Foundation) and the Sustainable India Finance Facility (UNEP, the World Agroforestry Centre, and BNP Paribas). This can be of substantial benefit to farmers, rural people, and the economy of Andhra Pradesh.

Chapter 4 concludes that CNF community enhances social capital. Although social capital is a complex concept to measure, our study constructed a comprehensive social capital index at the farmers' level using a multidimensional framework for three districts in Andhra Pradesh. We hypothesized that social capital would have positive productivity gains for the farmers and that women play a crucial role in facilitating community farming. The results show quite an interesting pattern. The means test indicated that the comprehensive social capital index is significantly higher in villages practising community farming than in non-CNF villages. Of the various dimensions of the social capital, information provision, collective action, and perception to risk significantly influence productivity. However, these three dimensions of social capital were insignificant for non-CNF farmers. We also found that women play a significant role in enhancing the region's social capital, as women are passive decision-makers in farming. The CNF farming workers influence the SHG community to discuss natural farming practices, which would then indirectly influence the men in the family. The study also showed that the smallholder and marginal farmers benefit from the social capital and farming collectively more than the prosperous farmers.

Agricultural policies need to consider the creation of social capital among farmers as an integral part of the planning process and emphasize connectedness with nature as the core of farming. This can enable the farmers to better harness the opportunities created by collective action and information provision. Some effort is required to encourage collective action among the farmers. Collective action facilitates sharing of farm inputs (including the expensive technology). For example, borewells are expensive to install, and not all farmers can afford them. However, collective action and community support might enable farmers to share the expensive technologies that otherwise are untenable for smallholder farmers. Social capital does not mean ensuring cooperation at the farmers' level alone but is also required at all levels – communities, governments, supply chains, etc. Cooperation and collaboration among all these actors are essential for sustainable natural farming. Such movements are taking shape, such as Andhra Pradesh CNF projects and Project Sahaj. However, greater impetus is required to leverage the potential of social capital through such movements.

Chapter 5 demonstrates that use of chemical inputs such as pesticides and fertilizers lead to higher incidences of short-term exposure and symptoms such as headache, sweating, nausea, and burning of eyes. This, in turn, leads to material health costs and productivity losses, which are a negative externality for farmers and unaccounted in traditional market-based crop-pricing models. CNF farmers have both, lower total economic impact of on-farm health ailments (INR 2,31,522) as well as lower average economic losses per farmer (INR 821) compared to chemical-intensive farming practices (INR 3,13,740 and INR 1,120, respectively). Inadequate practices such as not using PPE, improper storage, and not taking necessary precautions after application are key factors determining incidences of exposure, leading to health impacts for farmers/farm labour. Going forward, it is important to address both the lack of information available and on-farm awareness in following proper handling and disposal practices so farmers can mitigate the number of incidences and economic impacts of health risks due to agricultural input exposure.

With respect to the long-term health impacts on farmers and farmer households, a larger data set and timeseries data is needed to analyze the links between occurrence of material ailments (including cancer) for non-CNF and CNF practitioners going forward. The HDDS provides some interesting insights. CNF farmer households do tend to consume more varied diets compared to their counterparts, but, despite this, no household (CNF or counterfactual) consumes a complete diet (comprising of all 12 food groups covered in HDDS study). Farmer households in Andhra Pradesh, even those with higher-than-average incomes, do not consume enough fruits and non-dairy protein. This points toward cultural preferences and embedded food habits as the major causes for the limited diets.

The role of subsidies is a key determinant in the adoption of existing agricultural practices. In the absence of holistic measures of the true cost of food – i.e., the environmental, human, social, and financial costs – stakeholders cannot make informed choices. What ends up being adopted at scale is an unsustainable agri-food ecosystem dependent on monocropping and extensive energy and chemical-input subsidies, which generates significant negative environmental and human health externalities. Our study clearly demonstrates that alternative practices, such as CNF, have a much

lower on-farm human health cost while simultaneously enhancing the accessibility of rural households to more diverse foods and diets.

There is need to explore the impacts of such field studies on agricultural policy so that mechanisms can be developed to incentivize sustainable agricultural practices. Future studies can also investigate the impacts of food produced using CNF principles on the health and well-being of consumers.

As demonstrated in this study, the TEEBAgriFood Evaluation Framework is effective and multidisciplinary, allowing comprehensive comparison of different farming systems. It clearly showed that CNF is effective and better than conventional farming systems in terms of its economic, social, and health impacts. It is also evident from the growing number of farmers joining this just transition of farming systems at the grassroot level (led by RySS and collaborators). Such assessments are needed at the national and global scale so that appropriate policy responses can be developed. The results of this assessment encourage a redesign of farming systems to include CNF in order to improve the economic and social well-being, as well as the health, of the farming community in India and globally.

Appendix-1: Principal component analysis

Assuming that there are P variables, $x_1, x_2, x_3, \dots x_P$, much of the variance in the data can often be explained by a small number of variables called principal components, or a linear combination of the original variables using Z variables, $Z_1, Z_2, Z_3, \dots Z_P$, that are uncorrelated. Initially, there are still P principal components until we select the first, say, $L < P$ principal components that preserve a "high" amount of the cumulative variance of the original data. The weights a_{ij} (also called component or factor loadings) applied to the variables x_j in the above set of equations are chosen so that the principal components Z_i remain uncorrelated (orthogonal). The first principal component accounts for the maximum possible proportion of the variance of the set of x, and the consecutive ones account for the maximum of the remaining variance until the last principal component absorbs all the remaining variance not accounted for by the primary components. The sum of squares of weights for each principal component must be equal to 1, as follows:

$$a_{i1}^2 + a_{i2}^2 + \cdots + a_{iP}^2 = 1, i = 1, 2, \dots, P$$

Where P is the number of original variables. PCA involves findings of the eigenvalues $\lambda_j, j = 1, \dots, P$ of the sample covariance matrix ("CM"),

$$CM = \begin{bmatrix} cm_{11} & \cdots & cm_{1P} \\ \vdots & \ddots & \vdots \\ cm_{p1} & \cdots & cm_{PP} \end{bmatrix}$$

1) where the diagonal element cm_{ii} is the variance of x_i, and cm_{ij} is the covariance of variables x_i and x_j. The eigenvalues of the CM are the variances of the principal components and can be found by solving the characteristic equation $|CM - \lambda I| = 0$, where I is the identity matrix with the same order as CM, and λ is the vector of eigenvalues. There are P eigenvalues, some of which may be negligible. Negative eigenvalues are not possible for a covariance matrix. An important property of the eigenvalues is that they add up to the sum of the diagonal elements of CM. That is, the sum of the variances of the principal components is equal to the sum of the variances of the original variables:

$$\lambda_P + \lambda_P + \cdots + \lambda_P = cm_{11} + cm_{22} + \cdots + cm_{PP}$$

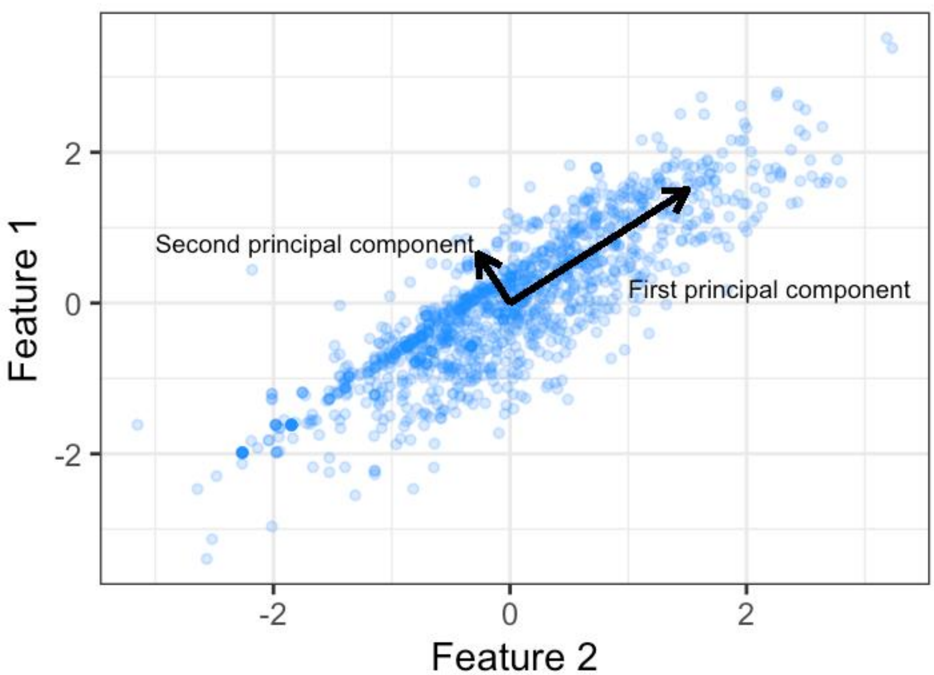
$$\lambda_P + \lambda_P + \cdots + \lambda_P = cm_{11} + cm_{22} + \cdots + cm_{PP}$$

$$\propto_c = \left(\frac{Q}{Q-1}\right)\frac{\sum_{i \neq j} cov(x_i, x_j)}{var(x_0)} = \left(\frac{Q}{Q-1}\right)\left(1 - \frac{\sum_j var(x_j)}{var(x_0)}\right) \; where\ c = 1, \dots, M; i, j$$

$$= 1, \dots, Q;\ x_0 = \sum_{q=1}^{0} x_j$$

where M indicates the number of entities considered, Q the number of individual indicators, and x_0 is the sum of all individual indicators. $\propto_c$ measures the portion of the total variability of the sample of individual indicators due to the correlation among all indicators. It increases with the number of individual indicators and each pair's covariance. If no correlation exists, then $\propto_c$ is equal to zero, else one for perfect correlation. A high $\propto_c$ indicates that the individual indicators measure the latent phenomenon well. Once the weights are assigned to different principal components, each village's social capital index (SCI) has been estimated using the additive aggregation procedure, as it assumes total compensation among indicators.

Figure 33: Example of a principal component analysis on a 2-dimentional data set



Source: https://us06web.zoom.us/j/93566298626?pwd=bTFjdFdtSllVNlNzNGpSVEM0cGk2QT09

Appendix-2: Description of the study villages

Table 38: Sampling for CNF

District	Cluster	Village	CNF village/ Counterfactual village	Sample size (No. of households)	Total no. of households	Agroclimatic zone	Average annual rainfall (mm)	Main crops
Vizianagaram	Mantinavalasa	Durbili	CNF village	24	69	Tribal hill zone	1,000	Rice and millets
	Outside the cluster	Gujjuvai	Counterfactual village	24	85	Tribal hill zone	1,000	Rice and millets
	Kondabaridi	Kondabaridi	CNF village	24	80	Tribal hill zone	1,000	Rice and millets
	Outside the cluster	G. Sivada	Counterfactual village	24	95	Tribal hill zone	1,000	Rice and millets
Anantapuramu	Melavoi	Melavoi	CNF village	68	395	Scarce rainfall	360	Groundnuts, vegetables, maize, finger millet (ragi)
	Melavoi	Amidalagondi	Counterfactual village	66	290	Scarce rainfall	360	Groundnuts, vegetables, maize, finger millet (ragi)
	Gunduvaripalli	Gunduvaripalli	CNF village	50	680	Scarce rainfall	440	Groundnut, maize

	Gunduvaripalli	Mohammadabad	Counterfactual village	50	1,040	Scarce rainfall	440	Groundnut, maize
West Godavari	Koppaka	Ammapalem	CNF village	76	712	Krishna-Godavari climate zone	220	Rice, corn maize, lemon
	Koppaka	Singaram	Counterfactual village	58	311	Krishna-Godavari climate zone	220	Paddy, maize
	Dharmavaram	Kapavaram	CNF village	40	889	Krishna-Godavari climate zone	200	Paddy, banana
	Dharmavaram	Kumaradevam	Counterfactual village	58	1,064	Krishna-Godavari climate zone	200	Paddy, banana
			Total sample size	562				

Source: RySS, 2021.

1. Duribili

Duribili village is in Kurupam Mandal of Parvathipuram agency area in Vizianagaram District of Andhra Pradesh. The village is remote, with poor network connectivity, and has limited access to transportation facilities. There are 71 households in the village, and all the villagers practice "Podu" agriculture. (Podu agriculture is an amalgam of cashew plantation, banana plantation with turmeric as an intercrop, and black-eyed beans, black gram, millets, maize, sesame, and vegetables.) Approximately 60 ha of land is cultivated during the kharif season and is rainfed. The villagers are involved in collecting and selling tamarind and mahua, and make a living by selling broomsticks. The village is known for its resistance to chemical fertilizer use and has not used chemical fertilizers for three decades. Due to the increase in cashew plantations, there has been a substantial decline in the rearing of goats, sheep, cows, and buffaloes. The farmers of Duribili are known to respect their field territories. Theft is uncommon despite the opportunity to loot the produce (cashews) of neighbouring fields. The villagers observe festivals collectively and participate in Shramdaans, mobilizing funds and feasting together.

2. **Kondabaridi**

Kondabaridi, located in Kurupam Mandal of Parvathipuram agency area of Vizianagaram District, has been declared the first village in Andhra Pradesh to have adopted 100% ZBNF on 1 December 2018. Of the 72 households in the village, 63 households practice agriculture. Most villagers depend on rainfed farming and practice agriculture in the kharif season. However, since 2012, the village has adopted the SRI paddy technique in the rabi season. The total land under cultivation in the village is 98.2 ha, of which 103.35 are under SRI paddy cultivation.

The villagers practice "Podu" agriculture, an amalgam of cashew plantation and other crops, namely red gram, black-eyed beans, green gram, and millets. The villagers also collect and sell tamarind and mahua. They mark and allot tamarind trees and collect the products collectively as a norm. In the village, there are 7 active women SHGs and 2 farmer SHGs. Two women SHGs have initiated a paddy procurement and processing centre (namely, Satya Gandhi Dampudu Biyyam Tayari Kendram), where they procure paddy at INR 15/kg and sell the processed waffle rice at INR 50/kg. They are currently supplying interstate clientele. Under the Annapurna model, 21 varieties of vegetables and fruits have been distributed to the farming households in the village. With the inculcation and practice of the SRI paddy technique, the seed rate and labour workforce have been reduced.

3. **G Sivada**

G Sivada is a tribal village with 163 households and 1,000 people, situated in the Kurupam Mandal of Vizianagaram District. The village is accessible by bus and auto rickshaws, and the connectivity is relatively poor. The agricultural markets and major health and educational services are located in Mondemkhallu village, 6 km from the village. The villagers are involved in entrepreneurship; the village had the highest number of petty businesses among all the sample villages in the district. The villagers depend on agriculture, labour, livestock rearing, dairy, private jobs, and government jobs for their livelihoods. Rainfed cultivation is predominant. Cashew cultivation with red gram, vegetables, and other millets as intercrops is favoured. The village depends on mahua and tamarind collection. While this village does not practice CNF, the farmers use negligible chemical inputs in their fields. Chemical-intensive farming was introduced 15 years ago, and few villagers have complained of stomach aches, tiredness, and swelling in the feet since switching to monocropping. Approximately 30 SHGs are active in the village, with each group having 13 to 15 members.

4. **Melavoi**

Melavoi is a village in the block of Madakasira and in the district of Anantapur, inland and far away from the coast. Its total population is 10,715, with 2,466 households. The village literacy rate is 56.3%, but among females the rate is lower (23%). The working population is 56% of the total, while the tribal population is 8.1% (870 individuals). In the village, the most common cultivated crop is groundnut. In addition:

- The total agricultural area is 2,271.09 ha, of which about 2,536.86 ha is un-irrigated.
- 80.93 ha is used permanent pastures and grazing lands.
- 161.87 ha is under miscellaneous tree crops.

- 288.54 ha is currently lying fallow.
- 103.59 ha is culturable waste land.
- 155.39 ha is lying as fallow land other than current fallows.
- 80.67 ha is covered by barren and uncultivable land.[5]

5. Amidalagondi

Very close to Melavoi (about 10 km away), Amidalagondi counts a total population of 5,900 people in 1,350 households. Of those, 165 people are tribal (2.8%). "There is a high level of women's participation in farming," said Seema Kulkarni, member of the national facilitation team at Mahila Kisan Adhikar Manch (MAKAAM).

6. Gujjuvai

Gujjuvai is a tribal village in the Kurupam Mandal of Vizianagaram District. There are 600 people in 84 households. There is limited connectivity in the village. Through a concept called "Bagu Bandha," the farmers avail loans by securing land; in return, the lender controls the land – this means tenant farming is practised until the loan is repaid. The nearest village with access to significant services is 4 km away. Of the total households, 15 households do not have cattle. Savara tribes house the village. Rainfed farming and cultivated kharif crops are predominant in the region, but some farmers grow rabi crops. The villagers apply goat manure to the fields. The village has four farmer groups, and buys chemicals and seeds from a shop located within the village.

7. Gunduvaripalli

Gunduvaripalli village is in Amadagur Mandal of Anantapur District, belonging to the Rayalaseema region. Anantapur is a dry, drought-prone district in Andhra Pradesh. Of the 146 households listed in the village, 101 practice agriculture, and 41 are partial – seed to seed practitioners of CNF. There are 8 poorest of the poor families. Drylands and red soils are predominant in the village, and the villagers mainly practice rainfed farming and grow crops in the kharif season; some farmers grow vegetables under irrigated conditions. Multicropping and intercropping are predominant. About 20 of the families migrate annually to Bengaluru, Karnataka, in search of work due to uncertainty in rainfed agriculture. In the village, about 4 ha of common land are used for collecting firewood and grazing. Most pesticides are not administered on the lands (as they practise rainfed agriculture). The fertilizers commonly used are DAP, Urea, Complex, SSP, and Gypsum. The lease rate for agricultural lands per year varies between INR 5,000 to INR 20,000, based on the availability and access to a

[5] See (http://geolysis.com/p/in/ap/anantapur/madakasira/melavoi).

source of irrigation. The Andhra Pradesh Grameena Vikas Banks avail crop loans and crop insurance to the farmers in the village.

8. Mohammadabad

Mohammadabad village is located in Amadaguru Mandal in the Anantapur District of the Rayalaseema region and is a small business hub. There are a sizable number of petty shops visible in the village. High school and Rural Development Trust schools, Grameen Bank, and Mee Seva centre are accessible to the village residents. Out of 270 households, 154 households practise agriculture. Farmers have been using chemicals on their farms for many years now. However, they are mainly limited to fertilizers and sparse pesticides. Pesticide administration is evident only in irrigated lands, which are usually used to grow vegetables (tomato, chilly, brinjal) and paddy. Red soil is prevalent in this area. The lease rate in the village varied from INR 1,000 to 12,500/ha a year. Tenancy–tenure deeds were uncommon in the village. The village is primarily rainfed, with minimal irrigated land. Out of the 150 borewells, only 12 borewells are in operation, with groundwater levels at 1500 feet. Borewell installation is not viable, as it costs INR 200,000 to 300,000 (owing to its uncertainty), thus restricting the farmers from cultivating kharif crops. Due to the uncertainty of rainfed farming, the villagers migrate to Bangalore and Kadri in search of work.

9. Kapavaram

Kapavaram village is in Kovvur Mandal of West Godavari District. Within the village, 40 households practice CNF. Of the 243 ha of land, plantain is harvested on 6 ha, vegetables on 6 ha, papaya on 1.2 ha, and the rest is used for paddy. The fields are fertile with good black soil. Most farmers have a borewell in their fields, and there is no water scarcity due to their proximity to the Godavari River. Mechanization is vivid here, especially during the paddy harvest. The farmers shifted from sugarcane to other crops like maize, plantain, and yam due to the closure of nearby sugar mills. There are 70 SHGs and one village organization. The land lease rate is INR 75,000 to INR 175,000 per ha per annum, which is hard to draw on for ZBNF lands due to reduced productivity. Sometimes, tenant farmers must pay rent in advance. Most fields are not insured (the chances of heavy rains and floods are frequent here). Farmers depend on migrant agricultural labourers from West Bengal, Bihar, and Odisha because the community here doesn't welcome women in the workforce (from higher castes). Farmers feel that certification will help the marketing of their products.

10. Kumaradevam

Kumaradevam is a large village in Kovvur Mandal of West Godavari District. The village has a population of 4,015, of which 1,911 are male and 2,104 are female (as per the 2011 population census). There are 1,220 families. The total cultivated land in the village is 647.5 ha. Farmers avail chemical inputs within the village and mainly depend on migrant agricultural labourers from West Bengal, Bihar, and Odisha because the community does not welcome women in the workforce. Productivity is higher in the rabi season than in the kharif season, which is uncommon. The village has a relatively higher administration of fertilizers, pesticides, and insecticides in the fields compared to Singavaram (see below).

11. Ammapalem

Ammapalem is a village located in Pedavegi Mandal of West Godavari District. The total population is approximately 2,800, comprised of about 700 households. Approximately 300 farmers practice agriculture in the village, of which 175 to 200 practice natural farming. Most farms are leased, with land lease rates INR 30,000 to 40,000. Most farmers cultivate on 0.2 to 2 ha. Paddy, maize, and vegetables are the main crops cultivated using natural farming techniques. Most of the farmers depend on external support. Premium markets are yet to be developed here for natural farming products.

12. Singavaram

Singavaram is a small village/hamlet in Pedavegi Mandal, West Godavari District. There are 381 households in the village, of which approximately 200 practice agriculture as their primary livelihood. Land lease rates are INR 30,000 to 40,000. Most of the farms are leased. The villagers have access to fertilizers/pesticides via the nearby town of Koppaka. Their main crops are paddy, maize, and vegetables. The soil is not graded, and they do not examine their soil before applying fertilizers. The village has 100% crop insurance and is reasonably technologically advanced

Appendix-3: Household questionnaire – Non-CNF farmer

APCNF TEEB Agri-Food Study

Questionnaire for on-field data collection- Non APCNF Farmers

Informed Consent for Interview

This study is being conducted to understand and demonstrate the impacts of APCNF practices as compared to other traditional chemical farming practices. For this, we would like to ask you few questions about your farming practices and well-being to understand the scenario better. Your answers will be kept completely confidential and will be used for research purpose only. You do not have to answer questions that you do not want to answer. You may decide to stop being a part of the research study at any time without explanation. However, we seek your cooperation in providing complete information. The interview will take about 1 hour.

Do you agree to participate in this study?	☐ Yes ☐ No

Household Identification No. (to be entered by enumerators)		
Interviewer Name		
Date of interview	_______(DD) / _______(MM) / ___________(YYYY)	
Village:	**Cluster:**	**District:**

1. **General Information.** *In this section, please provide general information about the primary respondent and household members.*

1.1. Primary Respondent Details	
1.1.1. Name	
1.1.2. Gender and Age	☐ Male Age ______________(Years) ☐ Female Age ______________(Years)
1.1.3. Education	☐ 1. No Schooling ☐ 2. Primary School (up to class 5th) ☐ 3. Secondary School (up to class 10th) ☐ 4. Senior Secondary School (up to class 12th) ☐ 5. Diploma but not graduate ☐ 6. Graduate ☐ 7. Post graduate ☐ 8. Others (Specify) ____________________________
1.1.4. Contact No. of Primary Respondent	

1.2. Household Size & Composition Total Household Members Composition by Gender and age.	 Nos. ________________ Male : _______ (<15 yrs.) __________ (15-60 yrs.) _________ (>60 yrs.) Female: _______ (<15 yrs.) __________ (15-60 yrs.) _________ (>60 yrs.)
1.3. Primary Source of Annual Income for the Household	☐ Agriculture Income (Rs.) _______________ ☐ Agri Labor Income (Rs.) _______________ ☐ Non-agriculture Labor Income (Rs.) _______________ ☐ Skilled worker/ Artisans Income (Rs.) _______________ ☐ Animal Husbandry Income (Rs.) _______________ ☐ Salaried (Government/Private). Income (Rs.) _______________ ☐ Small / HH industry Income (Rs.) _______________ ☐ Petty business/ shop Income (Rs.) _______________ ☐ Others (Specify) ______________ Income (Rs.) _______________
1.4. Secondary Source of Annual Income for the Household *(Choose one or multiple options as applicable)*	☐ Agriculture Income (Rs.) _______________ ☐ Agri Labor Income (Rs.) _______________ ☐ Non-agriculture Labor Income (Rs.) _______________ ☐ Skilled worker/ Artisans Income (Rs.) _______________ ☐ Animal Husbandry Income (Rs.) _______________ ☐ Salaried (Government/Private). Income (Rs.) _______________ ☐ Small / HH industry Income (Rs.) _______________ ☐ Petty business/ shop Income (Rs.) _______________ ☐ Others (Specify) ______________ Income (Rs.) _______________ ☐ Not Applicable
1.5. Colour of ration card	☐ 1. White ration card ☐ 2. Pink ration card ☐ 3. Antyodaya ration card
1.6. Social Category	☐ 1. General ☐ 2. OBC ☐ 3. SC/ST ☐ 4. Others

1.7. Agricultural Land Holding by Type *(Tick the appropriate unit for land as per data provided)*	☐ Owned ___________________________ (Area in Acre / Cent) ☐ Leased ☐ Shared cropping: Area_________ (Acre / Cent), Tenure ____(Years), Rent ________(Rs./ Year) ☐ Pure tenants Area_________ (Acre / Cent), Tenure ____(Years), Rent ________(Rs./ Year) ☐ Other (Specify)_________ Area_________ (Acre / Cent), Tenure ____(Years), Rent ________(Rs./ Year)
1.8. Total Cultivated Land *(Tick the appropriate unit for land as per data provided)*	___________________________________ (Area in Acre / Cent)
1.9. Total Irrigated Land *(Tick the appropriate unit for land as per data provided)*	____________________________________ (Area in Acre / Cent)
1.10. What is the area not under cultivation used for? *(Choose one or multiple options as applicable)*	☐ 1. Built infrastructure (house, storage structures, water structures, animal shed, farm shed etc.) ☐ 2. Grazing ☐ 3. Part of buffer zone ☐ 4. Fallow land ☐ 5. Non cultivable fallow land ☐ 6. Kept as barren for crop rotation ☐ 7. Leased out to other farmers ☐ 8. Others (Specify)______________________________________

2. Indicators of Social Capital			
2.1. Which groups/ organisations are you a member of? *(Provide information based on memberships held)*	☐ Farmer Group	☐ Self Help Group	☐ Others (Specify)____________
(Answer the question from 2.2 to 2.8 for the based on your membership. If you are not member of any group, please skip to Q.2.9)			
2.2. How often does the association conduct meetings?	☐ 1. Every week ☐ 2. Fortnightly ☐ 3. Each month ☐ 4. Every two months ☐ 5. Once in three months ☐ 6. Once in six months ☐ 7. Once a year ☐ 8. Others (Specify) ________________	☐ 1. Every week ☐ 2. Fortnightly ☐ 3. Each month ☐ 4. Every two months ☐ 5. Once in three months ☐ 6. Once in six months ☐ 7. Once a year ☐ 8. Others (Specify) ________________	☐ 1. Every week ☐ 2. Fortnightly ☐ 3. Each month ☐ 4. Every two months ☐ 5. Once in three months ☐ 6. Once in six months ☐ 7. Once a year ☐ 8. Others (Specify) ________________
2.3. How many meetings were conducted in the May 2019 - May 2020?			
2.4. How many meetings you have attended in May 2019 - May 2020?			
2.5. How do you rate your participation in the meetings?	☐ 1. Inactive ☐ 2. Less active ☐ 3. Moderately active ☐ 4. Very active ☐ 5. Extremely active	☐ 1. Inactive ☐ 2. Less active ☐ 3. Moderately active ☐ 4. Very active ☐ 5. Extremely active	☐ 1. Inactive ☐ 2. Less active ☐ 3. Moderately active ☐ 4. Very active ☐ 5. Extremely active

<table>
<tr><td>2.6. Do you think, you have benefitted from being part of the group you are associated with?</td><td>☐ 1. No benefit
☐ 2. Not much beneficial
☐ 3. Fairly Beneficial
☐ 4. Very Beneficial
☐ 5. Extremely beneficial</td><td>☐ 1. No benefit
☐ 2. Not much beneficial
☐ 3. Fairly Beneficial
☐ 4. Very Beneficial
☐ 5. Extremely beneficial</td><td>☐ 1. No benefit
☐ 2. Not much beneficial
☐ 3. Fairly Beneficial
☐ 4. Very Beneficial
☐ 5. Extremely beneficial</td></tr>
<tr><td>2.7. In what ways did you benefit from the association with other groups? (Choose one or multiple options as applicable)</td><td>☐ 1. Better information sharing
☐ 2. Access to credit
☐ 3. Better access to agricultural inputs
☐ 4. Had better access to labour
☐ 5. Access to shared irrigation facilities
☐ 6. Had better access to markets
☐ 7. Other reasons (Specify)___________</td><td>☐ 1. Better information sharing
☐ 2. Access to credit
☐ 3. Better access to agricultural inputs
☐ 4. Had better access to labour
☐ 5. Access to shared irrigation facilities
☐ 6. Had better access to markets
☐ 7. Other reasons (Specify)___________</td><td>☐ 1. Better information sharing
☐ 2. Access to credit
☐ 3. Better access to agricultural inputs
☐ 4. Had better access to labour
☐ 5. Access to shared irrigation facilities
☐ 6. Had better access to markets
☐ 7. Other reasons (Specify)___________</td></tr>
<tr><td>2.8. Does this group include members from other castes as well?</td><td>☐ Yes
☐ No</td><td>☐ Yes
☐ No</td><td>☐ Yes
☐ No</td></tr>
<tr><td colspan="2">2.9. In case you are not part of associations, what are the possible reasons?</td><td colspan="2">☐ 1. No such associations exist
☐ 2. I do not like to be part of associations
☐ 3. I do not think I would benefit from such groups
☐ 4. Other reasons (Specify)________________</td></tr>
<tr><td colspan="2">2.10. Do you consult fellow farmers while taking production decisions (such as what to produce, what inputs to use, farming practices to follow)?</td><td colspan="2">☐ 1. Never
☐ 2. Rarely
☐ 3. Sometimes
☐ 4. Many times
☐ 5. Always</td></tr>
<tr><td colspan="2">2.11. Are members of your family involved in production decisions (such as what to produce, what inputs to use, farming practices to follow)?</td><td colspan="2">☐ 1. Never
☐ 2. Rarely
☐ 3. Sometimes
☐ 4. Many times
☐ 5. Always</td></tr>
</table>

2.12. Do you know whom to consult in case of further information / help required regarding farming practices, techniques, inputs?	☐ 1. Never ☐ 2. Rarely ☐ 3. Sometimes ☐ 4. Many times ☐ 5. Always
2.13. Do farmers in your village share information with you when they grow new varieties/use new methods of farming?	☐ 1. Never ☐ 2. Rarely ☐ 3. Sometimes ☐ 4. Many times ☐ 5. Always
2.14. Do you share your experiences of outcome of farming after the season is over with other farmers?	☐ 1. Never ☐ 2. Rarely ☐ 3. Sometimes ☐ 4. Many times ☐ 5. Always
2.15. What is the level of trust you have on people in your village especially when you look to them for support?	☐ 1. Cannot trust ☐ 2. Fair ☐ 3. Good faith ☐ 4. Very good ☐ 5. Excellent
2.16. What is your level of trust for traders to whom you sell your produce?	☐ 1. Not at all trustworthy ☐ 2. Fairly trustworthy ☐ 3. Trustworthy ☐ 4. Very trustworthy ☐ 5. Highly trust worthy
2.17. What is your level of trust for input sellers? (Pesticides / Fertilizers / Organic Inputs)	☐ 1. Not at all trustworthy ☐ 2. Fairly trustworthy ☐ 3. Trustworthy ☐ 4. Very trustworthy ☐ 5. Highly trust worthy

2.18. How do you rank your agricultural extension officers in their ability to provide technical information?	☐ 1. Do not provide good support ☐ 2. Fair ☐ 3. Good ☐ 4. Very good ☐ 5. Extremely good
2.19. Do you think non-governmental organisations will benefit your village?	☐ 1. Will not be beneficial ☐ 2. Will be fairly beneficial ☐ 3. Will be beneficial ☐ 4. Will be very beneficial ☐ 5. Will be highly beneficial
2.20. Do you think gram panchayats work for the interest of all villagers?	☐ 1. Never ☐ 2. Rarely ☐ 3. Sometimes ☐ 4. Many times ☐ 5. Always
2.21. Do people trust each other in your village for lending and borrowing?	☐ 1. No trust at all ☐ 2. Fairly trust each other ☐ 3. Somewhat trust each other ☐ 4. Very good trust ☐ 5. High trust
2.22. Does your farming community help in any unpaid volunteering activities for the community / village (eg. *'Shramdaan'*)?	☐ 1. Never ☐ 2. Rarely ☐ 3. Sometimes ☐ 4. Many times ☐ 5. Always
2.23. Do you support your fellow farmers in case of credit problems?	☐ 1. Never ☐ 2. Rarely ☐ 3. Sometimes ☐ 4. Many times ☐ 5. Always
2.24. Do you think farmer's cooperation helps reduce production risk?	☐ 1. Never ☐ 2. Rarely ☐ 3. Sometimes ☐ 4. Many times ☐ 5. Always

3. Farming Techniques. *Please provide information related to various farming practices followed by the respondent.*

3.1. Farming Practice Followed *(Choose one or multiple options as applicable)*	☐ Chemical Farming. ________ (Area in Acre / Cent) ______ (No of years practicing) ☐ Organic Farming. ________ (Area in Acre / Cent) ______ (No of years practicing) ☐ Tribal Farming. ________ (Area in Acre / Cent) ______ (No of years practicing) ☐ Low Input Rainfed Farming. ______ (Area in Acre / Cent) ______ (No of years practicing) ☐ Other Practices _________, _____ (Area in Acre / Cent) ______ (No of years practicing)

4. Farming Equipment and Other Inputs Requirement in last crop year

4.1. Which of the following do you own? *(Choose one or multiple options as applicable)*	☐ 1. Spades / Pick axe / Sickle ☐ 2. Tractor ☐ 3. Bullock Cart ☐ 4. Tiller ☐ 5. Weeder ☐ 6. Harvester ☐ 7. Planter ☐ 8. None ☐ 9. Other (Specify) __________________
4.2. How do you irrigate your land? *(Choose one or multiple options as applicable)*	☐ 1. River / Stream ☐ 2. Canal ☐ 3. Borewell ☐ 4. Well ☐ 5. Tank ☐ 6. Not Applicable (mark this in case of rainfed farming) ☐ 7. Others (Specify)__________________
4.3. How do you procure seeds for the farm?	☐ 1. Only individually ☐ 2. Mostly individually and sometimes collectively ☐ 3. Individually and collectively in equal proportions ☐ 4. Mostly collectively and sometimes individually ☐ 5. Always collectively
4.4. From where do you procure majority of the seeds for your farm? *(in case if you are procuring seeds from multiple sources please choose the option based on the place from where you do maximum procurement)*	☐ 1. Self ☐ 2. Local vendor in village ☐ 3. Farmer co-operative societies ☐ 4. Vendor outside village ☐ 5. Provided free of cost / subsidised by Government ☐ 6. Other farmers ☐ 7. Other

4.5. How much do you trust the above seed procuring agency?	☐ 1. Cannot trust ☐ 2. Fair ☐ 3. Good faith ☐ 4. Very good faith ☐ 5. No need to suspect at all
4.6. What is your source of technical information for farming? *(Choose one or multiple options as applicable)*	☐ 1. Other Farmers ☐ 2. RySS ☐ 3. Communication Media like radio/TV/ internet ☐ 4. Agricultural Extension ☐ 5. Farmer-based organization ☐ 6. Agriculture input agencies ☐ 7. Seed Companies ☐ 8. Traders (who buy farm produce) ☐ 9. Others (Specify) ___________________________
4.7. Have you availed agricultural credit?	☐ Yes ☐ No
4.7.1. Source of credit *(Choose one or multiple options as applicable)*	☐ 1. Banks ☐ 2. Cooperative Society ☐ 3. Relatives ☐ 4. Money Lender ☐ 5. Farmers Group ☐ 6. Self-Help Group ☐ 7. Others (Specify) ____________________________
4.7.2. What is the loan amount you have availed in the last year?	____ (Rs.)
4.7.3. What is the total loan repayment in the last year?	Interest ____________________________________ (Rs.) Principal amount _____________________________ (Rs.)
4.7.4. If not, why could you not access credit? *(Choose one or multiple options as applicable)*	☐ 1. High Interest Rate ☐ 2. Do not meet Credit Requirement ☐ 3. No Collateral ☐ 4. Do not need credit ☐ 5. Others (Specify) ____________________________

4.8. Do you receive any money through any government schemes?	☐ Yes ☐ No
4.9. If yes, what scheme do you receive money from?	________________________________ (text)
4.10. If yes, How much money did you receive in the last 1 year?	_________________________________ (Rs.)
4.11. Do you have agricultural insurance?	☐ Yes (Insurance Provider)______________________ (Premium paid) ______________________(Rs) ☐ No
4.12. Which trainings/ demonstrations did you attend regarding agriculture practices? *(Choose one or multiple options as applicable)*	☐ 1. Trainings on different farming practices ☐ 2. Intercropping / Mulching ☐ 3. Integrated Pest and Nutrient Management ☐ 4. Micro irrigation / irrigation management ☐ 5. Others (Specify) ___________________________ ☐ 6. None
4.13. Did you practice soil and water conservation such as farm bunding or contour bunding, etc.?	☐ 1. Only individually ☐ 2. Mostly individually and sometimes collectively ☐ 3. Individually and collectively in equal proportions ☐ 4. Mostly collectively and sometimes individually ☐ 5. Always collectively
4.14. Did you share labour especially when there is shortage?	☐ 1. Never ☐ 2. Rarely ☐ 3. Sometimes ☐ 4. Many times ☐ 5. Always

4.15. Do you sell your produce collectively?	☐ 1. Only individually ☐ 2. Mostly individually and sometimes collectively ☐ 3. Sometimes individually and sometimes collectively ☐ 4. Most often collectively ☐ 5. Always collectively
4.16. What constraints do you face in farming? *(Choose one or multiple options as applicable)*	☐ 1. Lack of good quality seeds ☐ 2. Lack of agricultural labour ☐ 3. Lack of adequate irrigation facilities ☐ 4. High incidence of pests/ animal attacks ☐ 5. Natural calamities ☐ 6. Higher cost of fertilizers/ pesticides ☐ 7. Lack of technical support ☐ 8. High costs of farming ☐ 9. Lower returns to agriculture ☐ 10. Lack of storage facilities ☐ 11. Lack of premium markets for organic products ☐ 12. No constraints ☐ 13. Others (Specify) ____________________________
4.17. Was this year's crop yield less than the expected yield? If yes, choose reason for lower than expected yield?	☐ 1. Poor Germination ☐ 2. Incidence of pests ☐ 3. Nutrient deficiency ☐ 4. Irrigation related issues ☐ 5. Nature related problems ☐ 6. Lack of timely credit ☐ 7. Lack of timely support from extension officers ☐ 8. Unavailability of inputs as required ☐ 9. Not applicable ☐ 10. Others (Specify) ____________________________

5. Livestock Ownership Details & Livestock Incomes in last cropping year

	No. (at the end of last cropping year)	**Total Rearing cost (Rs/Year)**	**Total Income Received (Rs. /Year)** *(Through sale of produce or livestock)*
5.1. Cows			
5.2. Buffaloes			
5.3. Sheep/ Goats			
5.4. Pigs			
5.5. Poultry			
5.6. Ducks			
5.7. Beekeeping			
5.8. Fish			
5.9. Other____________			

6. Labour Utilization in last cropping year – Write down the total no. of days worked in each column. *(For example, in Kharif season 2 Females in the family worked for 8 days each, write 2*8 =16 in the column)*

	Family Labour			**Hired labour**	
	Male	**Female**	**Children (<14)**	**Male**	**Female**
Kharif					
Rabi					
Summer / Zaid					
Perennial					

6.1. What is the common mode of payment for hired labour?	☐ Money ☐ In exchange of produce ☐ In exchange of working on their farms ☐ In lieu of old debt ☐ Others (Specify) ____________________
6.2. What is the farming activity for which you required maximum labour	☐ Land preparation ☐ Sowing ☐ Harvesting ☐ Weeding ☐ Pesticide application ☐ Post harvesting operations ☐ Others (Specify) ____________________

7. Plot-wise crop summary - **if the farmer is having only plot wise data for these items please capture the total cost for that plot for that season. No need to capture it crop wise.*

7.1. Kharif

Plot 1:			**Area :**			**(Acre / Cent)**				
Sr. No.	**Crop Name**	**Production**		**Price per unit** (in Rs.)	**Cost of Seeds** (in Rs.)	**Cost of Machinery*** (in Rs.)	**Cost of Labour*** (in Rs.)	**Cost of Inputs*** (fertilizers, pesticides) (in Rs.)	**Other Costs** (transportation cost, middleman etc.) (in Rs.)
		Unit	**Quantity**						
1.									
2.									
3.									
4.									
5.									

Plot 2:			**Area :**			(Acre / Cent)			
Sr. No.	**Crop Name**	**Production**		**Price per unit** (in Rs.)	**Cost of Seeds** (in Rs.)	**Cost of Machinery*** (in Rs.)	**Cost of Labour*** (in Rs.)	**Cost of Inputs*** (in Rs.)	**Other costs** (in Rs.)
		Unit	**Quantity**						
1.									
2.									
3.									
4.									
5.									

Plot 3*:			**Area** :			(Acre / Cent)			
Sr. No.	**Crop Name**	**Production**		**Price per unit** (in Rs.)	**Cost of Seeds** (in Rs.)	**Cost of Machinery*** (in Rs.)	**Cost of Labour*** (in Rs.)	**Cost of Inputs*** (in Rs.)	**Other costs** (in Rs.)
		Unit	**Quantity**						
1.									
2.									
3.									
4.									
5.									

7.2. Rabi

Plot 1:			Area :			(Acre / Cent)			
Sr. No.	**Crop Name**	**Production**		**Price per unit** (in Rs.)	**Cost of Seeds** (in Rs.)	**Cost of Machinery*** (in Rs.)	**Cost of Labour*** (in Rs.)	**Cost of Inputs*** (in Rs.)	**Other costs** (in Rs.)
		Unit	**Quantity**						
1.									
2.									
3.									
4.									
5.									

Plot 2:			Area :			(Acre / Cent)			
Sr. No.	**Crop Name**	**Production**		**Price per unit** (in Rs.)	**Cost of Seeds** (in Rs.)	**Cost of Machinery*** (in Rs.)	**Cost of Labour*** (in Rs.)	**Cost of Inputs*** (in Rs.)	**Other costs** (in Rs.)
		Unit	**Quantity**						
1.									
2.									
3.									
4.									
5.									

Plot 3*:			Area :			(Acre / Cent)			
Sr. No.	**Crop Name**	**Production**		**Price per unit** (in Rs.)	**Cost of Seeds** (in Rs.)	**Cost of Machinery*** (in Rs.)	**Cost of Labour*** (in Rs.)	**Cost of Inputs*** (in Rs.)	**Other costs** (in Rs.)
		Unit	**Quantity**						
1.									
2.									
3.									
4.									
5.									

7.3. Summer

Plot 1:			Area :		(Acre / Cent)				
Sr. No.	**Crop Name**	**Production**		**Price per unit** (in Rs.)	**Cost of Seeds** (in Rs.)	**Cost of Machinery*** (in Rs.)	**Cost of Labour*** (in Rs.)	**Cost of Inputs*** (in Rs.)	**Other costs** (in Rs.)
		Unit	**Quantity**						
1.									
2.									
3.									
4.									
5.									

Plot 2:			Area :		(Acre / Cent)				
Sr. No.	**Crop Name**	**Production**		**Price per unit** (in Rs.)	**Cost of Seeds** (in Rs.)	**Cost of Machinery*** (in Rs.)	**Cost of Labour*** (in Rs.)	**Cost of Inputs*** (in Rs.)	**Other costs** (in Rs.)
		Unit	**Quantity**						
1.									
2.									
3.									
4.									
5.									

Plot 3*:				Area :			(Acre / Cent)		
Sr. No.	**Crop Name**	**Production**		**Price per unit** (in Rs.)	**Cost of Seeds** (in Rs.)	**Cost of Machinery*** (in Rs.)	**Cost of Labour*** (in Rs.)	**Cost of Inputs*** (in Rs.)	**Other costs** (in Rs.)
		Unit	**Quantity**						
1.									
2.									
3.									
4.									
5.									

7.4. Perennial Crop

Plot 1:			Area :		(Acre / Cent)					
Sr. No.	**Crop Name**	**Production**		**Price per unit** (in Rs.)	**Cost of Seeds** (in Rs.)	**Cost of Machinery*** (in Rs.)	**Cost of Labour*** (in Rs.)	**Cost of Inputs*** (in Rs.)	**Other costs** (in Rs.)
		Unit	**Quantity**						
1.									
2.									
3.									
4.									
5.									

Plot 2:			Area :		(Acre / Cent)					
Sr. No.	**Crop Name**	**Production**		**Price per unit** (in Rs.)	**Cost of Seeds** (in Rs.)	**Cost of Machinery*** (in Rs.)	**Cost of Labour*** (in Rs.)	**Cost of Inputs*** (in Rs.)	**Other costs** (in Rs.)
		Unit	**Quantity**						
1.									
2.									
3.									
4.									
5.									

Plot 3*:			Area :		(Acre / Cent)					
Sr. No.	**Crop Name**	**Production**		**Price per unit** (in Rs.)	**Cost of Seeds** (in Rs.)	**Cost of Machinery*** (in Rs.)	**Cost of Labour*** (in Rs.)	**Cost of Inputs*** (in Rs.)	**Other costs** (in Rs.)
		Unit	**Quantity**						
1.									
2.									
3.									
4.									
5.									

**Use addendum 2 if there are more than 3 plots.*

8. Perception Related to Farm Inputs: *This section is designed to understand the perception of the respondent with respect to the use of various chemical inputs.*

8.1. Are you aware of the adverse health impacts caused by chemical inputs?	☐ Yes ☐ No
8.1.1. If Yes, and current farming practice uses chemical inputs, why do you continue to use chemical inputs in your farm? *(Choose one or multiple options as applicable)*	☐ 1. Don't have technical knowhow about alternative farming practices ☐ 2. Higher yield than other farming practices ☐ 3. Lower cultivation cost than other farming practices ☐ 4. Farm inputs are easily available than other farming practices ☐ 5. Chemical inputs provide quick and instant removal of pests ☐ 6. Chemical inputs are easier to apply ☐ 7. Chemical inputs are more effective ☐ 8. Other (Specify) ________________________________ ____(Text)
8.2. Are you aware of the colour codes used in the pesticide bottles or containers to indicate the toxicity level of pesticides?	☐ Yes ☐ No
8.3. Have you attended any training about pest management?	☐ Yes ☐ No
8.4. Have you been provided with safety instructions on how to use chemical inputs in your local language either in training or while purchasing?	☐ Yes ☐ No
8.5. Have you stopped using certain chemical inputs in the past?	☐ Yes ☐ No
8.5.1. If yes, name of the chemical input.	____ (Text)
8.5.2. Why did you stop using the chemical input?	☐ 1. No longer available ☐ 2. Noticed health issues due to use ☐ 3. Found cheaper alternative ☐ 4. Found better alternative ☐ 5. Alternative suggested by input dealer ☐ 6. Alternative suggested by agriculture extension officer ☐ 7. No longer functions on pests / soil as expected ☐ 8. Other (Specify) _____________________________ (Text)
8.5.3. If yes, what is the replacement chemical input you use currently?	____ (Text)

8.6. Are you aware of the APCNF farming practice?	☐ Yes ☐ No
8.6.1. If yes, from whom did you come to know about the APCNF farming practice? *(Choose one or multiple options as applicable)*	☐ 1. Ry.S.S. ☐ 2. Other Farmers ☐ 3. Print Media / Radio ☐ 4. Cluster Cadres ☐ 5. Internet / YouTube ☐ 6. Other ______________________________ (Specify)
8.6.2. If yes, do you intend to completely / partially shift to APCNF farming practice?	☐ Yes If Yes, Why? ____________________________________ ____ ☐ No If No, Why not? __________________________________ ____

***9. Fertilizer Use-** Please fill this section based on the fertilizers used by farmer in the last cropping year for cultivating various crops.*

Sr. No.	Input Name	Quantity Used in field (Kg)	Total Cost (Rs.)	Source of procurement	Plots where applied	Method of application
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						

Source of procurement: 1. Own preparation, 2. Local vendor in village, 3. Farmer co-operative societies, 4. Vendor outside village, 5. Government store, 6. Other Farmers, 7. Other.
Methods of application: 1. Broadcasting, 2. Placement, 3. Starter solutions, 4. Foliar application, 5. Application through irrigation water (Fertigation), 6. Injection into soil, 7. Other.

10. Practices and personal behaviors related to the use of fertilizers. *Please fill this section based on the practices and personal behavior followed by the respondent in the purchase, storage, usage and disposal of fertilizers.*

10.1. Preparation of Fertilizer

10.1.1. Where do you store the fertilizer? (before application and the leftover after application) *(Choose one or multiple options as applicable)*	☐ 1. Separate room / godown outside house ☐ 2. In a separate room in House ☐ 3. In house but not in separate room ☐ 4. In animal shed ☐ 5. In farm shed ☐ 6. Openly ☐ 7. Others ________________________ (Specify)

10.1.2. Who handles the fertilizer during the preparation stage? Also indicate number of people involved.

☐ Male HH members ________________ (Number)	☐ Female HH members ________________ (Number)	☐ Male Agri Laborer ________________ (Number)	☐ Female Agri Laborer ________________ (Number)

10.1.3. What precautions are taken while preparing the fertilizers? *(Choose one or multiple options as applicable)*	☐ No precaution ☐ Wear protective gloves ☐ Use stick for handling ☐ Others ________________________ (Specify)

10.2. Application of Fertilizer

10.2.1. Who applies the fertilizer on the farm? Also indicate the number of people involved.

☐ Male HH members ________________ (Number)	☐ Female HH members ________________ (Number)	☐ Male Agri Laborer ________________ (Number)	☐ Female Agri Laborer ________________ (Number)

10.2.2. Indicate the use of personal protective equipment and personal practices performed during the application of fertilizer. *(Choose one or multiple options as applicable)*	☐ 1. No precaution ☐ 2. Face / Eye mask ☐ 3. Gloves ☐ 4. Specific shoes ☐ 5. Specific clothes / impermeable clothes / long sleeved clothes ☐ 6. Hat / Hood ☐ 7. Consume food and/or water ☐ 8. Drink alcohol and/or smoking and/or chewing gum
10.3. Post-application Practices	
10.3.1. Indicate the personal practices undertaken after applying fertilizer? *(Choose one or multiple options as applicable)*	☐ 1. Replace/clean face mask, gloves and/or filters ☐ 2. Wash hands and feet with soap ☐ 3. Wash hands and feet without soap ☐ 4. Take bath after spraying ☐ 5. Wash clothing after spraying ☐ 6. Change clothes ☐ 7. Wash application equipment used ☐ 8. Wait 24 hours before reentering the field ☐ 9. Consume food/water immediately ☐ 10. Drink alcohol and/or smoking and/or chewing gum immediately ☐ 11. Others ________________________ (Specify)
10.3.2. How do you dispose the bottle/package? *(Choose one or multiple options as applicable)*	☐ 1. Puncture and collection for safe disposal ☐ 2. Washing and Reusing of the container/ bag ☐ 3. Washing at home/ field ☐ 4. Washing at nearby water body ☐ 5. Burn the container/ bag ☐ 6. Bury the container/ bag ☐ 7. Leave it in the field ☐ 8. Others ________________________ (Specify)

11. Pesticide / Herbicide Use –*Please fill this section based on the pesticides / herbicides used by farmer in the last cropping year for cultivating various crops.*

Sr. No	Input Name	Quantity Used (in ml)	Total Cost (in Rs.)	Source of procurement	Plots/ crops in which application done	Methods of application	Pests controlled
1.							
2.							
3.							
4.							
5.							
6.							
7.							
8.							
9.							
10.							

Source of procurement: 1. Own preparation, 2. Local vendor in village, 3. Farmer co-operative societies, 4. Vendor outside village, 5. Government store, 6. Other Farmers, 7. Other.

Methods of application: 1. Broadcasting, 2. Placement, 3. Starter solutions, 4. Foliar application, 5. Application through irrigation water (Fertigation), 6. Injection into soil, 7. Others

12. Practices and personal behaviors related to the use of pesticides / herbicides *Please fill this section based on the practices and personal behavior followed by the respondent in the purchase, storage, usage and disposal of pesticide / herbicide*

12.1. Preparation of pesticide / herbicide

12.1.1. Where do you store the pesticide / herbicide? (before application and the leftover pesticide / herbicide after application) *(Choose one or multiple options as applicable)*	☐ 1. Separate room /godown outside house ☐ 2. In a separate room in House ☐ 3. In house but not in separate room ☐ 4. In animal shed ☐ 5. In farm shed ☐ 6. Openly ☐ 7. Other ______________________ (Specify)

12.1.2. Who handles the pesticide / herbicide during the preparation stage? Also indicate number of people involved.

Male HH members __________ (Number)	☐ Female HH members __________ (Number)	☐ Male Agri Laborer __________ (Number)	☐ Female Agri Laborer __________ (Number)

12.1.3. What precautions are taken while preparing the pesticide / herbicide? *(Choose one or multiple options as applicable)*	☐ 1. No precaution ☐ 2. Wear protective gloves ☐ 3. Use stick for handling ☐ 4. Other ______________________ (Specify)

12.2. Application of pesticide / herbicide

12.2.1. Method of application of pesticide / herbicide	☐ 1. Dusting ☐ 2. Spraying ☐ 3. Root zone application ☐ 4. Seedling root dip ☐ 5. Soil drenching ☐ 6. Other ______________________ (Specify)

12.2.2. Who applies the pesticide / herbicide on the farm? Also indicate the number of people involved.

☐ Male HH members __________ (Number)	☐ Female HH members __________ (Number)	☐ Male Agri Laborer __________ (Number)	☐ Female Agri Laborer __________ (Number)

12.2.3. Indicate the use of personal protective equipment and personal practices performed during the application of pesticides / herbicides. *(Choose one or multiple options as applicable)*	☐ 1. No precaution ☐ 2. Face / Eye mask ☐ 3. Gloves ☐ 4. Specific shoes ☐ 5. Specific clothes / impermeable clothes / long sleeved clothes ☐ 6. Hat / Hood ☐ 7. Consume food and/or water ☐ 8. Drink alcohol and/or smoking and/or chewing gum
12.3. Post-application Practices	
12.3.1. Indicate the personal practices undertaken after applying pesticide / herbicide? *(Choose one or multiple options as applicable)*	☐ 1. Replace/clean face mask, gloves and/or filters ☐ 2. Wash hands and feet with soap ☐ 3. Wash hands and feet without soap ☐ 4. Take bath after spraying ☐ 5. Wash clothing after spraying ☐ 6. Change clothes ☐ 7. Wash application equipment used ☐ 8. Wait 24 hours before reentering the field ☐ 9. Consume food/water immediately ☐ 10. Drink alcohol and/or smoking and/or chewing gum immediately ☐ 11. Other ___________________________ (Specify)
12.3.2. How do you dispose the bottle/package? *(Choose one or multiple options as applicable)*	☐ 1. Puncture and collection for safe disposal ☐ 2. Washing and Reusing of the container ☐ 3. Washing at home / field ☐ 4. Washing at nearby water body ☐ 5. Burn the container ☐ 6. Bury the container ☐ 7. Leave it in the field ☐ 8. Sell it to scrap dealer ☐ 9. Other ___________________________ (Specify)

13. ***Other Organic inputs.*** *Please fill this section based on the organic inputs (cow dung, compost etc) used for cultivating various crops.*

Sr. No.	Input Name	Quantity used in the field		Cost per unit (in Rs.)	Source of procurement	Plots where applied	Methods of application
		Unit	Amount				
1.							
2.							
3.							
4.							
5.							
6.							
7.							
8.							
9.							
10.							

Source of procurement: 1. Own preparation, 2. Local vendor in village, 3. Farmer co-operative societies, 4. Vendor outside village, 5. Government store, 6. Other Farmers, 7. Other.

Methods of application: 1. Broadcasting, 2. Placement, 3. Starter solutions, 4. Foliar application, 5. Application through irrigation water (Fertigation), 6. Injection into soil, 7.

14. Practices and personal behaviors related to the use of organic inputs. *Please fill this section based on the practices and personal behavior followed by the respondent in the purchase, storage, usage of organic inputs.*

14.1. Preparation stage

14.1.1. Where do you store the organic inputs? (before application and the leftover after application) *(Choose one or multiple options as applicable)*	☐ 1. Separate room /godown outside house ☐ 2. In a separate room in House ☐ 3. In house but not in separate room ☐ 4. In animal shed ☐ 5. In farm shed ☐ 6. Openly ☐ 7. Other ________________________ (Specify)

14.1.2. Who handles the organic input during the preparation stage? Also indicate number of people involved?

Male HH members	Female HH members	Male Agri Laborer	Female Agri Laborer
__________ (Nos)	___________ (Nos)	____________(Nos)	____________ (Nos)

14.1.3. Indicate the use of personal protective equipment and personal practices performed during the application of organic inputs. *(Choose one or multiple options as applicable)*	☐ 1. No precaution ☐ 2. Face / Eye mask ☐ 3. Gloves ☐ 4. Specific shoes ☐ 5. Specific clothes / impermeable clothes / long sleeved clothes ☐ 6. Hat / Hood ☐ 7. Consume food and/or water ☐ 8. Drink alcohol and/or smoking and/or chewing gum

14.2. Post-application Practices

14.2.1. Indicate the personal practices undertaken after applying organic inputs? *(Choose one or multiple options as applicable)*	☐ 1. Replace/clean face mask, gloves and/or filters ☐ 2. Wash hands and feet with soap ☐ 3. Wash hands and feet without soap ☐ 4. Take bath after spraying ☐ 5. Wash clothing after spraying ☐ 6. Change cloths ☐ 7. Wash application equipment used ☐ 8. Wait 24 hours before reentering the field ☐ 9. Consume food/water immediately ☐ 10. Drink alcohol and/or smoking and/or chewing gum immediately ☐ 11. Other ________________________ (Specify)

15. Symptoms developed due to on-farm activities: Please answer the below questions based on the symptoms developed during the preparation and application or after the application of Pesticides, Fertilizers, Organic Inputs etc. (*Tick symptoms as applicable*)

Organic input	Chemical fertilizers	Pesticides / herbicides / insecticides
☐ Headache	☐ Headache	☐ Headache
☐ Excessive sweating	☐ Excessive sweating	☐ Excessive sweating
☐ Burning eyes	☐ Burning eyes	☐ Burning eyes
☐ Excessive tearing	☐ Excessive tearing	☐ Excessive tearing
☐ Running nose	☐ Running nose	☐ Running nose
☐ Short of breath	☐ Short of breath	☐ Short of breath
☐ Excessive salivation	☐ Excessive salivation	☐ Excessive salivation
☐ Skin rashes	☐ Skin rashes	☐ Skin rashes
☐ Vomiting	☐ Vomiting	☐ Vomiting
☐ Nausea	☐ Nausea	☐ Nausea
☐ Dizziness	☐ Dizziness	☐ Dizziness
☐ Blurred vision	☐ Blurred vision	☐ Blurred vision
☐ Staggering gait	☐ Staggering gait	☐ Staggering gait
☐ Muscle cramp	☐ Muscle cramp	☐ Muscle cramp
☐ Twitching eye lid	☐ Twitching eye lid	☐ Twitching eye lid
☐ Tremor	☐ Tremor	☐ Tremor
☐ Loss of consciousness	☐ Loss of consciousness	☐ Loss of consciousness
☐ Seizure	☐ Seizure	☐ Seizure

16. Chemical Poisoning. *This section relates to incidents of poisoning due to any chemicals used in farming activities (pesticide, rodenticide, etc). Please include only incidents of poising occurring while preparation applying or exposure to the field.*

DO NOT include incidents of poisoning due to deliberate intake of pesticides or any other chemicals used in farming activities.

16.1. How many incidents of chemical poisoning do you recollect occurring during the past one year?	Number of incidents: ________________ Who was affected by chemical poisoning? ________________
16.2. If there are instances of chemical poisoning answer the following questions.	
16.2.1. Type of symptoms developed	________________ (Text)
16.2.2. Nature of treatment taken	________________ (Text)
16.2.3. Cost incurred in the treatment per incident	________________ (Rs)
16.2.4. Average number of productive days lost per incident	________________ (Days)

17. Health expenditure for the last year

17.1.1. How many times do you visit the hospital in the last year?	________________(Number)
17.1.2. How much do you spend in the last year on medical expenses?	________________(Rs.)
17.1.3. For what health problems did you have to visit the hospital? Also include all health problem you or members of your family are under medication for.	

18. Diseases due to on-farm activities. *Please answer the below questions based on the diseases which you are aware you or any of your family members involved in direct farming activities are suffering from in the past one year (tick provide details as applicable).*

18.1. Hypertension	☐ How long have you been suffering ____________ ☐ Treatments taken- Yes. No ☐ Where did you take the treatment ____________ ☐ Cost incurred in last cropping year ____________ ☐ Total number of productive days lost in last cropping year____________
18.2. Cholesterol	☐ How long have you been suffering ____________ ☐ Treatments taken- Yes. No ☐ Where did you take the treatment ____________ ☐ Cost incurred in last cropping year ____________ ☐ Total number of productive days lost in last cropping year____________
18.3. Asthma	☐ How long have you been suffering ____________ ☐ Treatments taken- Yes. No ☐ Where did you take the treatment ____________ ☐ Cost incurred in last cropping year ____________ ☐ Total number of productive days lost in last cropping year____________
18.4. Rheumatoid Arthritis	☐ How long have you been suffering ____________ ☐ Treatments taken- Yes. No ☐ Where did you take the treatment ____________ ☐ Cost incurred in last cropping year ____________ ☐ Total number of productive days lost in last cropping year____________
18.5. Skin irritation, pigmentation	☐ How long have you been suffering ____________ ☐ Treatments taken- Yes. No ☐ Where did you take the treatment ____________ ☐ Cost incurred in last cropping year ____________ ☐ Total number of productive days lost in last cropping year____________
18.6. Conjunctivitis	☐ How long have you been suffering ____________ ☐ Treatments taken- Yes. No ☐ Where did you take the treatment ____________ ☐ Cost incurred in last cropping year ____________ ☐ Total number of productive days lost in last cropping year____________

18.7. Tuberculosis	☐ How long have you been suffering ________________ ☐ Treatments taken- Yes. No ☐ Where did you take the treatment ________________ ☐ Cost incurred in last cropping year ________________ ☐ Total number of productive days lost in last cropping year________
18.8. Chronic cough	☐ How long have you been suffering ________________ ☐ Treatments taken- Yes. No ☐ Where did you take the treatment ________________ ☐ Cost incurred in last cropping year ________________ ☐ Total number of productive days lost in last cropping year________
18.9. Diarrhoea	☐ How long have you been suffering ________________ ☐ Treatments taken- Yes. No ☐ Where did you take the treatment ________________ ☐ Cost incurred in last cropping year ________________ ☐ Total number of productive days lost in last cropping year________
18.10. Kidney disorders	☐ How long have you been suffering ________________ ☐ Treatments taken- Yes. No ☐ Where did you take the treatment ________________ ☐ Cost incurred in last cropping year ________________ ☐ Total number of productive days lost in last cropping year________
18.11. Back pain	☐ How long have you been suffering ________________ ☐ Treatments taken- Yes. No ☐ Where did you take the treatment ________________ ☐ Cost incurred in last cropping year ________________ ☐ Total number of productive days lost in last cropping year________
18.12. Pain in joints	☐ How long have you been suffering ________________ ☐ Treatments taken- Yes. No ☐ Where did you take the treatment ________________ ☐ Cost incurred in last cropping year ________________ ☐ Total number of productive days lost in last cropping year________
18.13. Sleep disorders	☐ How long have you been suffering ________________ ☐ Treatments taken- Yes. No ☐ Where did you take the treatment ________________ ☐ Cost incurred in last cropping year ________________ ☐ Total number of productive days lost in last cropping year________

18.14. Thyroid	☐ How long have you been suffering ________________ ☐ Treatments taken- Yes. No ☐ Where did you take the treatment ________________ ☐ Cost incurred in last cropping year ________________ ☐ Total number of productive days lost in last cropping year________
18.15. Cancer	
18.15.1. Brain cancer	☐ How long have you been suffering ________________ ☐ Treatments taken- Yes. No ☐ Where did you take the treatment ________________ ☐ Cost incurred in last cropping year ________________ ☐ Total number of productive days lost in last cropping year________
18.15.2. Lung Cancer	☐ How long have you been suffering ________________ ☐ Treatments taken- Yes. No ☐ Where did you take the treatment ________________ ☐ Cost incurred in last cropping year ________________ ☐ Total number of productive days lost in last cropping year________
18.15.3. Laryngeal Cancer	☐ How long have you been suffering ________________ ☐ Treatments taken- Yes. No ☐ Where did you take the treatment ________________ ☐ Cost incurred in last cropping year ________________ ☐ Total number of productive days lost in last cropping year________
18.15.4. Prostate Cancer	☐ How long have you been suffering ________________ ☐ Treatments taken- Yes. No ☐ Where did you take the treatment ________________ ☐ Cost incurred in last cropping year ________________ ☐ Total number of productive days lost in last cropping year________
18.15.5. Other types of Cancer (Please specify________)	☐ How long have you been suffering ________________ ☐ Treatments taken- Yes. No ☐ Where did you take the treatment ________________ ☐ Cost incurred in last cropping year ________________ ☐ Total number of productive days lost in last cropping year________
18.16. Any other diseases (Please specify ____________)	☐ How long have you been suffering ________________ ☐ Treatments taken- Yes. No ☐ Where did you take the treatment ________________ ☐ Cost incurred in last cropping year ________________ ☐ Total number of productive days lost in last cropping year________

19. Changes observed over the years	
19.1. Have the number of crops you have cultivated changed over the years?	☐ Increase ☐ No change ☐ Decrease
19.2. How do crop yields changed over the years?	☐ Increase ☐ No change ☐ Decrease
19.3. How has the productivity of farm animals changed over the years?	☐ Increase ☐ No change ☐ Decrease
19.4. Have you noticed any changes in the health of you and your family over the years?	☐ Improved ☐ Same ☐ Declined
19.5. How has your fertilizer use changed over the last 5 years?	☐ Increased ☐ No change ☐ Decreased
19.6. How has your pesticide use changed over the years?	☐ Increased ☐ No change ☐ Decreased
19.7. How has your expenditure on seeds and hired or bought machinery changed over the years?	☐ Increased ☐ No change ☐ Decreased
19.8. How has your expenditure on loans and interest changed over the years?	☐ Increased ☐ No change ☐ Decreased ☐ Not applicable
19.9. Have you noticed any changes to your health or the health of your family over the years?	☐ Health problems reduced ☐ No change ☐ Health problems increased

NOTES

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Appendix-4: Household questionnaire – APCNF farmers

APCNF TEEB Agri-Food Study

Questionnaire for on-field data collection - APCNF Farmers

Informed Consent for Interview

This study is being conducted to understand and demonstrate the impacts of APCNF practices as compared to other traditional chemical farming practices. For this, we would like to ask you few questions about your farming practices and well-being to understand the scenario better. Your answers will be kept completely confidential and will be used for research purpose only. You do not have to answer questions that you do not want to answer. You may decide to stop being a part of the research study at any time without explanation. However, we seek your cooperation in providing complete information. The interview will take about 1 hour.

Do you agree to participate in this study?	☐ Yes ☐ No

Household Identification No. (to be entered by enumerators)		
Interviewer Name		
Date of interview	_______(DD) / _________(MM) / __________(YYYY)	
Village:	**Cluster:**	**District:**

1. General Information. *In this section, please provide general information about the primary respondent and household members.*

1.1. Primary Respondent Details

1.1.1. Name	
1.1.2. Gender and Age	☐ Male Age ____________(Years) ☐ Female Age ____________(Years)
1.1.3. Education	☐ 1. No Schooling ☐ 2. Primary School (up to class 5th) ☐ 3. Secondary School (up to class 10th) ☐ 4. Senior Secondary School (up to class 12th) ☐ 5. Diploma but not graduate ☐ 6. Graduate ☐ 7. Post graduate ☐ 8. Others (Specify) ________________________
1.1.4. Contact Number of Primary Respondent	

1

1.2. Household Size & Composition	
Total Household Members	Nos. ________________
Composition by Gender and age	Male : _______ (<15 yrs.) __________ (15-60 yrs.) _________ (>60 yrs.) Female: _______ (<15 yrs.) __________ (15-60 yrs.) _________ (>60 yrs.)
1.3. Primary Source of Annual Income for the Household	☐ Agriculture Income (Rs.) _______________ ☐ Agri Labor Income (Rs.) _______________ ☐ Non-agriculture Labor Income (Rs.) _______________ ☐ Skilled worker/ Artisans Income (Rs.) _______________ ☐ Animal Husbandry Income (Rs.) _______________ ☐ Salaried (Government/Private). Income (Rs.) _______________ ☐ Small / HH industry Income (Rs.) _______________ ☐ Petty business/ shop Income (Rs.) _______________ ☐ Others (Specify) ______________ Income (Rs.) _______________
1.4. Secondary Source of Annual Income for the Household *(Choose one or multiple options as applicable)*	☐ Agriculture Income (Rs.) _______________ ☐ Agri Labor Income (Rs.) _______________ ☐ Non-agriculture Labor Income (Rs.) _______________ ☐ Skilled worker/ Artisans Income (Rs.) _______________ ☐ Animal Husbandry Income (Rs.) _______________ ☐ Salaried (Government/Private). Income (Rs.) _______________ ☐ Small / HH industry Income (Rs.) _______________ ☐ Petty business/ shop Income (Rs.) _______________ ☐ Others (Specify) ______________ Income (Rs.) _______________ ☐ Not Applicable
1.5. Colour of ration card	☐ 1. White ration card ☐ 2. Pink ration card ☐ 3. Antyodaya ration card
1.6. Social Category	☐ 1. General ☐ 2. OBC ☐ 3. SC/ST ☐ 4. Others

1.7. Agricultural Land Holding by Type *(Tick the appropriate unit for land as per data provided)*	☐ Owned ___________________________ (Area in Acre / Cent) ☐ Leased ☐ Shared cropping: Area_________ (Acre / Cent), Tenure ____(Years), Rent _______________________ (Rs./ Year) ☐ Pure tenants Area_________ (Acre / Cent), Tenure ____(Years), Rent ____________________ (Rs./ Year) ☐ Other (Specify)_________ Area_________ (Acre / Cent), Tenure ____(Years), Rent ___________________ (Rs./ Year)
1.8. Total Cultivated Land *(Tick the appropriate unit for land as per data provided)*	___________________________________ (Area in Acre / Cent)
1.9. Total Irrigated Land *(Tick the appropriate unit for land as per data provided)*	____________________________________ (Area in Acre / Cent)
1.10. What is the area not under cultivation used for? *(Choose one or multiple options as applicable)*	☐ 1. Built infrastructure (house, storage structures, water structures, animal shed, farm shed etc.) ☐ 2. Grazing ☐ 3. Part of buffer zone ☐ 4. Fallow land ☐ 5. Non cultivable fallow land ☐ 6. Kept as barren for crop rotation ☐ 7. Leased out to other farmers ☐ 8. Others (Specify)_____________________________________

2. Indicators of Social Capital			
2.1. Which groups/ organisations are you a member of? *(Provide information based on memberships held)*	☐ Farmer Group	☐ Self Help Group	☐ Others (Specify)____________
(Answer the question from 2.2 to 2.8 for the based on your membership. If you are not member of any group, please skip to Q.2.9)			
2.2. How often does the association conduct meetings?	☐ 1. Every week ☐ 2. Fortnightly ☐ 3. Each month ☐ 4. Every two months ☐ 5. Once in three months ☐ 6. Once in six months ☐ 7. Once a year ☐ 8. Others (Specify) _________________	☐ 1. Every week ☐ 2. Fortnightly ☐ 3. Each month ☐ 4. Every two months ☐ 5. Once in three months ☐ 6. Once in six months ☐ 7. Once a year ☐ 8. Others (Specify) _________________	☐ 1. Every week ☐ 2. Fortnightly ☐ 3. Each month ☐ 4. Every two months ☐ 5. Once in three months ☐ 6. Once in six months ☐ 7. Once a year ☐ 8. Others (Specify) _________________
2.3. How many meetings were conducted in the last cropping year?			
2.4. How many meetings you have attended in the last cropping year?			
2.5. How do you rate your participation in the meetings?	☐ 1. Inactive ☐ 2. Less active ☐ 3. Moderately active ☐ 4. Very active ☐ 5. Extremely active	☐ 1. Inactive ☐ 2. Less active ☐ 3. Moderately active ☐ 4. Very active ☐ 5. Extremely active	☐ 1. Inactive ☐ 2. Less active ☐ 3. Moderately active ☐ 4. Very active ☐ 5. Extremely active

2.6. Do you think, you have benefitted from being part of the group you are associated with?	☐ 1. No benefit ☐ 2. Not much beneficial ☐ 3. Fairly Beneficial ☐ 4. Very Beneficial ☐ 5. Extremely beneficial	☐ 1. No benefit ☐ 2. Not much beneficial ☐ 3. Fairly Beneficial ☐ 4. Very Beneficial ☐ 5. Extremely beneficial	☐ 1. No benefit ☐ 2. Not much beneficial ☐ 3. Fairly Beneficial ☐ 4. Very Beneficial ☐ 5. Extremely beneficial
2.7. In what ways did you benefit from the association with other groups? *(Choose one or multiple options as applicable)*	☐ 1. Better information sharing ☐ 2. Access to credit ☐ 3. Better access to agricultural inputs ☐ 4. Had better access to labour ☐ 5. Access to shared irrigation facilities ☐ 6. Had better access to markets ☐ 7. Other reasons (Specify)___________	☐ 1. Better information sharing ☐ 2. Access to credit ☐ 3. Better access to agricultural inputs ☐ 4. Had better access to labour ☐ 5. Access to shared irrigation facilities ☐ 6. Had better access to markets ☐ 7. Other reasons (Specify)___________	☐ 1. Better information sharing ☐ 2. Access to credit ☐ 3. Better access to agricultural inputs ☐ 4. Had better access to labour ☐ 5. Access to shared irrigation facilities ☐ 6. Had better access to markets ☐ 7. Other reasons (Specify)___________
2.8. Does this group include members from other castes as well?	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No
2.9. In case you are not part of associations, what are the possible reasons?		☐ 1. No such associations exist ☐ 2. I do not like to be part of associations ☐ 3. I do not think I would benefit from such groups ☐ 4. Other reasons (Specify)________________	
2.10. Do you consult fellow farmers while taking production decisions (such as what to produce, what inputs to use, farming practices to follow)?		☐ 1. Never ☐ 2. Rarely ☐ 3. Sometimes ☐ 4. Many times ☐ 5. Always	
2.11. Are members of your family involved in production decisions (such as what to produce, what inputs to use, farming practices to follow)?		☐ 1. Never ☐ 2. Rarely ☐ 3. Sometimes ☐ 4. Many times ☐ 5. Always	

2.12. Do you know whom to consult in case of further information / help required regarding farming practices, techniques, inputs?	☐ 1. Never ☐ 2. Rarely ☐ 3. Sometimes ☐ 4. Many times ☐ 5. Always
2.13. Do farmers in your village share information with you when they grow new varieties/use new methods of farming?	☐ 1. Never ☐ 2. Rarely ☐ 3. Sometimes ☐ 4. Many times ☐ 5. Always
2.14. Do you share your experiences of outcome of farming after the season is over with other farmers?	☐ 1. Never ☐ 2. Rarely ☐ 3. Sometimes ☐ 4. Many times ☐ 5. Always
2.15. What is the level of trust you have on people in your village especially when you look to them for support?	☐ 1. Cannot trust ☐ 2. Fair ☐ 3. Good faith ☐ 4. Very good ☐ 5. Excellent
2.16. What is your level of trust for traders to whom you sell your produce?	☐ 1. Not at all trustworthy ☐ 2. Fairly trustworthy ☐ 3. Trustworthy ☐ 4. Very trustworthy ☐ 5. Highly trust worthy
2.17. What is your level of trust for input (Jeevamrutham, Beejamrutham etc.) sellers?	☐ 1. Not at all trustworthy ☐ 2. Fairly trustworthy ☐ 3. Trustworthy ☐ 4. Very trustworthy ☐ 5. Highly trust worthy ☐ 0. Not Applicable

2.18. How do you rank your agricultural extension officers in their ability to provide technical information?	☐ 1. Do not provide good support ☐ 2. Fair ☐ 3. Good ☐ 4. Very good ☐ 5. Extremely good
2.19. Do you think non-governmental organisations will benefit your village?	☐ 1. Will not be beneficial ☐ 2. Will be fairly beneficial ☐ 3. Will be beneficial ☐ 4. Will be very beneficial ☐ 5. Will be highly beneficial
2.20. Do you think gram panchayats work for the interest of all villagers?	☐ 1. Never ☐ 2. Rarely ☐ 3. Sometimes ☐ 4. Many times ☐ 5. Always
2.21. Do people trust each other in your village for lending and borrowing?	☐ 1. No trust at all ☐ 2. Fairly trust each other ☐ 3. Somewhat trust each other ☐ 4. Very good trust ☐ 5. High trust
2.22. Does your farming community help in any unpaid volunteering activities for the community / village (eg. *'Shramdaan'*)?	☐ 1. Never ☐ 2. Rarely ☐ 3. Sometimes ☐ 4. Many times ☐ 5. Always
2.23. Do you support your fellow farmers in case of credit problems?	☐ 1. Never ☐ 2. Rarely ☐ 3. Sometimes ☐ 4. Many times ☐ 5. Always
2.24. Do you think farmer's cooperation helps reduce production risk?	☐ 1. Never ☐ 2. Rarely ☐ 3. Sometimes ☐ 4. Many times ☐ 5. Always

2.25. How do you rank your APCNF cadre in their ability to provide technical information?	☐ 1. No support ☐ 2. Fair support ☐ 3. Good support ☐ 4. Very good support ☐ 5. Extremely good support
2.26. Do you think the CRPs help address any problems associated to farming in the village?	☐ 1. No benefit ☐ 2. Not much beneficial ☐ 3. Fairly Beneficial ☐ 4. Very Beneficial ☐ 5. Extremely beneficial
2.27. Do you think the ICRPs help address any problems associated to farming in the village?	☐ 1. No benefit ☐ 2. Not much beneficial ☐ 3. Fairly Beneficial ☐ 4. Very Beneficial ☐ 5. Extremely beneficial

3. Farming Techniques. *Please provide information related to various farming practices followed by the respondent.*

3.1. Farming Practice Followed *(Choose one or multiple options as applicable)*	☐ APCNF ______ (Area in Acre / Cent) _______ (No of years practicing) ☐ Other Traditional Farming Practices* ☐ Chemical Farming. ________ (Area in Acre / Cent) ______ (No of years practicing) ☐ Organic Farming. ________ (Area in Acre / Cent) ______ (No of years practicing) ☐ Tribal Farming. ________ (Area in Acre / Cent) ______ (No of years practicing) ☐ Low Input Rainfed Farming. ______ (Area in Acre / Cent) ______ (No of years practicing) ☐ Other Practices _________, _____ (Area in Acre / Cent) ______ (No of years practicing)

*(In case if the farmer is also practicing other farming practices please also use the addendum no. 1)

4. **Farming Equipment and Other Inputs Requirement in the last cropping year**	
4.1. Which of the following do you own? *(Choose one or multiple options as applicable)*	☐ 1. Spades / Pick axe / Sickle ☐ 2. Tractor ☐ 3. Bullock Cart ☐ 4. Tiller ☐ 5. Weeder ☐ 6. Harvester ☐ 7. Planter ☐ 8. None ☐ 9. Other (Specify) __________________
4.2. How do you irrigate your land? *(Choose one or multiple options as applicable)*	☐ 1. River / Stream ☐ 2. Canal ☐ 3. Borewell ☐ 4. Well ☐ 5. Tank ☐ 6. Not Applicable (mark this option in case of rainfed farming) ☐ 7. Others (Specify)__________________
4.3. How do you procure seeds and other inputs for the farm?	☐ 1. Only individually ☐ 2. Mostly individually and sometimes collectively ☐ 3. Individually and collectively in equal proportions ☐ 4. Mostly collectively and sometimes individually ☐ 5. Always collectively
4.4. From where do you procure majority of the seeds for your farm? *(in case if you are procuring seeds from multiple sources please choose the option based on the place from where you do maximum procurement)*	☐ 1. Self ☐ 2. Local vendor in village ☐ 3. Farmer co-operative societies ☐ 4. Vendor outside village ☐ 5. Provided free of cost / subsidised by Government ☐ 6. Other farmers ☐ 7. Other
4.5. How much do you trust the input sellers (like seeds, chemicals, fertilizers)?	☐ 1. Cannot trust ☐ 2. Fair ☐ 3. Good faith ☐ 4. Very good faith ☐ 5. No need to suspect at all

4.6. What is your source of technical information for farming? *(Choose one or multiple options as applicable)*	☐ 1. Other Farmers ☐ 2. RySS ☐ 3. Communication Media like radio/TV/ internet ☐ 4. Agricultural Extension ☐ 5. Farmer-based organization ☐ 6. Agriculture input agencies ☐ 7. Seed Companies ☐ 8. Traders (who buy farm produce) ☐ 9. Others (Specify) ________________________
4.7. Have you availed agricultural credit?	☐ Yes ☐ No
4.7.1. Source of credit *(Choose one or multiple options as applicable)*	☐ 1. Banks ☐ 2. Cooperative Society ☐ 3. Relatives ☐ 4. Money Lender ☐ 5. Farmers Group ☐ 6. Self-Help Group ☐ 7. Others (Specify) ________________________
4.7.2. What is the loan amount you have availed in the last year?	____ (Rs.)
4.7.3. What is the total loan repayment in the last year?	Interest __________________________________ (Rs.) Principal amount ___________________________ (Rs.)
4.7.4. If not, why could you not access credit? *(Choose one or multiple options as applicable)*	☐ 1. High Interest Rate ☐ 2. Do not meet Credit Requirement ☐ 3. No Collateral ☐ 4. Do not need credit ☐ 5. Others (Specify) ________________________
4.8. Do you receive any money through any government schemes?	☐ Yes ☐ No
4.8.1. If yes, what scheme do you receive money from?	____ (text)
4.8.2. If yes, How much money did you receive in the last 1 year?	____ (Rs.)

4.9. Do you have agricultural insurance?	☐ Yes (Insurance Provider)_______________________ (Premium paid) _______________________(Rs) ☐ No
4.10. Which trainings/ demonstrations did you attend regarding agriculture practices? *(Choose one or multiple options as applicable)*	☐ 1. Trainings on APCNF ☐ 2. Intercropping / Mulching ☐ 3. Integrated Pest and Nutrient Management ☐ 4. Micro irrigation / irrigation management ☐ 5. Others (Specify) ____________________________ ☐ 6. None
4.11. Did you practice soil and water conservation such as farm bunding etc.?	☐ 1. Only individually ☐ 2. Mostly individually and sometimes collectively ☐ 3. Individually and collectively in equal proportions ☐ 4. Mostly collectively and sometimes individually ☐ 5. Always collectively
4.12. Did you share labour especially when there is shortage?	☐ 1. Never ☐ 2. Rarely ☐ 3. Sometimes ☐ 4. Many times ☐ 5. Always
4.13. Do you sell your produce collectively?	☐ 1. Only individually ☐ 2. Mostly individually and sometimes collectively ☐ 3. Sometimes individually and sometimes collectively ☐ 4. Most often collectively ☐ 5. Always collectively
4.14. What constraints do you face in farming? *(Choose one or multiple options as applicable)*	☐ 1. Lack of good quality seeds ☐ 2. Lack of agricultural labour ☐ 3. Lack of adequate irrigation facilities ☐ 4. High incidence of pests/ animal attacks ☐ 5. Natural calamities ☐ 6. Higher cost of fertilizers/ pesticides ☐ 7. Lack of technical support ☐ 8. High costs of farming ☐ 9. Lower returns to agriculture ☐ 10. Lack of storage facilities ☐ 11. Lack of premium markets for organic products ☐ 12. No constraints ☐ 13. Others (Specify) _____________________________

4.15. Was this year's crop yield less than the expected yield? If yes, choose reason for lower than expected yield? *(Choose one or multiple options as applicable)*	☐ 1. Poor Germination ☐ 2. Incidence of pests ☐ 3. Nutrient deficiency ☐ 4. Irrigation related issues ☐ 5. Nature related problems ☐ 6. Lack of timely credit ☐ 7. Lack of timely support from extension officers ☐ 8. Unavailability of inputs as required ☐ 9. Not applicable ☐ 10. Others (Specify) ________________________

5. Livestock Ownership Details & Livestock Incomes in the last cropping year

	No. (at the end of last cropping year)	**Total Rearing cost (Rs/Year)**	**Total Income Received (Rs. /Year)** *(Through sale of produce or livestock)*
5.1. Cows			
5.2. Buffaloes			
5.3. Sheep			
5.4. Goats			
5.5. Pigs			
5.6. Poultry			
5.7. Ducks			
5.8. Beekeeping			
5.9. Fish			
5.10. Other____________			

6. Labour Utilization in the last cropping year – Write down the total no. of days worked in each column. *(For example, in Kharif season 2 Females in the family worked for 8 days each, write 2*8 =16 in the column)*

	Family Labour			Hired labour	
	Male	**Female**	**Children (<14)**	**Male**	**Female**
Kharif					
Rabi					
Summer / Zaid					
Perennial					

6.1. What is the common mode of payment for hired labour?	☐ 1. Money ☐ 2. In exchange of produce ☐ 3. In exchange of working on their farms ☐ 4. In lieu of old debt ☐ 5. Others (Specify) ____________________
6.2. What is the farming activity for which you required maximum labour	☐ 1. Land preparation ☐ 2. Sowing ☐ 3. Weeding ☐ 4. Application of farm inputs ☐ 5. Harvesting ☐ 6. Post harvesting operations ☐ 7. Others (Specify) ____________________

7. Plot-wise crop summary : **if the farmer is having only plot wise data for these items please capture the total cost for that plot for that season. No need to capture it crop wise.*

7.1. Kharif

Plot 1:		**Area :**	**(Acre / Cent)**

Sr. No.	**Crop Name**	**Production**		**Price per unit** (in Rs.)	**Cost of Seeds** (in Rs.)	**Cost of Machinery***(in Rs.)	**Cost of Labour*** (in Rs.)	**Cost of Inputs*** (jivamrutham ,bijamrutham etc.) (in Rs.)	**Other Costs** (transportation cost, middleman etc.) (in Rs.)
		Unit	**Quantity**						
1.									
2.									
3.									
4.									
5.									

Plot 2:		**Area :**	(Acre / Cent)

Sr. No.	**Crop Name**	**Production**		**Price per unit** (in Rs.)	**Cost of Seeds** (in Rs.)	**Cost of Machinery*** (in Rs.)	**Cost of Labour*** (in Rs.)	**Cost of Inputs*** (in Rs.)	**Other costs** (in Rs.)
		Unit	**Quantity**						
1.									
2.									
3.									
4.									
5.									

Plot 3:**		**Area** :	(Acre / Cent)

Sr. No.	**Crop Name**	**Production**		**Price per unit** (in Rs.)	**Cost of Seeds** (in Rs.)	**Cost of Machinery*** (in Rs.)	**Cost of Labour*** (in Rs.)	**Cost of Inputs*** (in Rs.)	**Other costs** (in Rs.)
		Unit	**Quantity**						
1.									
2.									
3.									
4.									
5.									

7.2. Rabi

Plot 1:			Area :			(Acre / Cent)			
Sr. No.	**Crop Name**	**Production**		**Price per unit** (in Rs.)	**Cost of Seeds** (in Rs.)	**Cost of Machinery*** (in Rs.)	**Cost of Labour*** (in Rs.)	**Cost of Inputs** *(in Rs.)	**Other costs** (in Rs.)
		Unit	**Quantity**						
1.									
2.									
3.									
4.									
5.									

Plot 2:			Area :			(Acre / Cent)			
Sr. No.	**Crop Name**	**Production**		**Price per unit** (in Rs.)	**Cost of Seeds** (in Rs.)	**Cost of Machinery*** (in Rs.)	**Cost of Labour*** (in Rs.)	**Cost of Inputs*** (in Rs.)	**Other costs** (in Rs.)
		Unit	**Quantity**						
1.									
2.									
3.									
4.									
5.									

Plot 3**:			Area :			(Acre / Cent)			
Sr. No.	**Crop Name**	**Production**		**Price per unit** (in Rs.)	**Cost of Seeds** (in Rs.)	**Cost of Machinery*** (in Rs.)	**Cost of Labour*** (in Rs.)	**Cost of Inputs*** (in Rs.)	**Other costs** (in Rs.)
		Unit	**Quantity**						
1.									
2.									
3.									
4.									
5.									

7.3. Summer

Plot 1:		Area :			(Acre / Cent)				
Sr. No.	**Crop Name**	**Production**		**Price per unit** (in Rs.)	**Cost of Seeds** (in Rs.)	**Cost of Machinery*** (in Rs.)	**Cost of Labour** * (in Rs.)	**Cost of Inputs *** (in Rs.)	**Other costs** (in Rs.)
		Unit	**Quantity**						
1.									
2.									
3.									
4.									
5.									

Plot 2:		Area :			(Acre / Cent)				
Sr. No.	**Crop Name**	**Production**		**Price per unit** (in Rs.)	**Cost of Seeds** (in Rs.)	**Cost of Machinery*** (in Rs.)	**Cost of Labour*** (in Rs.)	**Cost of Inputs*** (in Rs.)	**Other costs** (in Rs.)
		Unit	**Quantity**						
1.									
2.									
3.									
4.									
5.									

Plot 3**:		Area :			(Acre / Cent)				
Sr. No.	**Crop Name**	**Production**		**Price per unit** (in Rs.)	**Cost of Seeds** (in Rs.)	**Cost of Machinery*** (in Rs.)	**Cost of Labour*** (in Rs.)	**Cost of Inputs*** (in Rs.)	**Other costs** (in Rs.)
		Unit	**Quantity**						
1.									
2.									
3.									
4.									
5.									

7.4. Perennial Crop

Plot 1:		Area : (Acre / Cent)							
Sr. No.	Crop Name	Production		Price per unit (in Rs.)	Cost of Seeds (in Rs.)	Cost of Machinery* (in Rs.)	Cost of Labour* (in Rs.)	Cost of Inputs* (in Rs.)	Other costs (in Rs.)
		Unit	Quantity						
1.									
2.									
3.									
4.									
5.									

Plot 2:		Area : (Acre / Cent)							
Sr. No.	Crop Name	Production		Price per unit (in Rs.)	Cost of Seeds (in Rs.)	Cost of Machinery* (in Rs.)	Cost of Labour* (in Rs.)	Cost of Inputs* (in Rs.)	Other costs (in Rs.)
		Unit	Quantity						
1.									
2.									
3.									
4.									
5.									

Plot 3**:		Area : (Acre / Cent)							
Sr. No.	Crop Name	Production		Price per unit (in Rs.)	Cost of Seeds (in Rs.)	Cost of Machinery* (in Rs.)	Cost of Labour* (in Rs.)	Cost of Inputs* (in Rs.)	Other costs (in Rs.)
		Unit	Quantity						
1.									
2.									
3.									
4.									
5.									

***Use addendum 2 if there are more than 3 plots.*

8. ***APCNF inputs -*** *Please fill this section based on the consumable inputs (Beejamrutham, Jeevamrutham etc) used by APCNF farmer for cultivating various crops.*

Sr. No.	Input Name	Quantity used in the field		Cost per unit (Rs.)	Source of procurement	Plots where applied	Methods of application
		Unit	Amount				
1.							
2.							
3.							
4.							
5.							
6.							
7.							
8.							
9.							
10.							

Source of procurement: 1. Own preparation, 2. Local vendor in village, 3. Farmer co-operative societies, 4. Vendor outside village, 5. Government store, 6. Other Farmers, 7. Other.

Methods of application: 1. Broadcasting, 2. Placement, 3. Starter solutions, 4. Foliar application, 5. Application through irrigation water (Fertigation), 6. Injection into soil, 7. Others

9. Practices and personal behaviors related to the use of APCNF inputs: *Please fill this section based on the practices and personal behavior followed by the respondent in the purchase, storage, usage of inputs mentioned in Q. 8.*

9.1. Preparation stage

9.1.1. Where do you store the APCNF inputs? (before application and the leftover after application) *(Choose one or multiple options as applicable)*	☐ 1. Separate room /godown outside house ☐ 2. In a separate room in House ☐ 3. In house but not in separate room ☐ 4. In animal shed ☐ 5. In farm shed ☐ 6. Openly ☐ 7. Other ____________________________ (Specify)

9.1.2. Who handles the APCNF input during the preparation stage? Also indicate number of people involved?

☐ Male HH members ___________________ (Number)	☐ Female HH members ___________________ (Number)	☐ Male Agri Laborer ___________________ (Number)	☐ Female Agri Laborer ___________________ (Number)

9.1.3. What precautions are taken while preparing the APCNF input? *(Choose one or multiple options as applicable)*	☐ No precaution ☐ Wear protective gloves ☐ Use stick for handling ☐ Other ____________________________ (Specify)

9.2. Application Stage

9.2.1. Who applies the APCNF input on the farm? Also indicate the number of people involved.

☐ Male HH members ___________________ (Number)	☐ Female HH members ___________________ (Number)	☐ Male Agri Laborer ___________________ (Number)	☐ Female Agri Laborer ___________________ (Number)

9.2.2. Indicate the use of personal protective equipment and personal practices performed during the application of APCNF inputs. *(Choose one or multiple options as applicable)*	☐ 1. No precaution ☐ 2. Face / Eye mask ☐ 3. Gloves ☐ 4. Specific shoes ☐ 5. Specific clothes / impermeable clothes / long sleeved clothes ☐ 6. Hat / Hood ☐ 7. Consume food and/or water ☐ 8. Drink alcohol and/or smoking and/or chewing gum
9.3. Post-application Stage	
9.3.1. Indicate the personal practices undertaken after applying APCNF inputs? *(Choose one or multiple options as applicable)*	☐ 1. Replace/clean face mask, gloves and/or filters ☐ 2. Wash hands and feet with soap ☐ 3. Wash hands and feet without soap ☐ 4. Take bath after spraying ☐ 5. Wash clothing after spraying ☐ 6. Change cloths ☐ 7. Wash application equipment used ☐ 8. Wait 24 hours before reentering the field ☐ 9. Consume food/water immediately ☐ 10. Drink alcohol and/or smoking and/or chewing gum immediately ☐ 11. Other ___________________________ (Specify)

10. Symptoms developed due to handling of farm inputs like jeevamrutham etc.: Please answer the below questions based on the symptoms developed during the preparation and application or after the application of farm inputs.

☐ Headache	☐ Short of breath	☐ Blurred vision
☐ Excessive sweating	☐ Excessive salivation	☐ Staggering gait
☐ Burning eyes	☐ Skin rashes	☐ Muscle cramp
☐ Excessive tearing	☐ Vomiting	☐ Twitching eye lid
☐ Running nose	☐ Nausea	☐ Tremor
☐ Seizure	☐ Dizziness	☐ Loss of consciousness

11. Health expenditure for the last year

11.1.1. How many times do you visit the hospital in the last year?	(Number)
11.1.2. How much do you spend in the last year on medical expenses?	(Rs.)
11.1.3. For what health problems did you have to visit the hospital? Also include all health problem you or members of your family are under medication for.	

12. Diseases or health problems faced by members of the family. *Please answer the below questions based on the diseases which you are aware you or any of your family members involved in direct farming activities are suffering from (tick provide details as applicable).*

12.1. Hypertension	☐ How long have you been suffering ________________ ☐ Treatments taken- Yes. No ☐ Where did you take the treatment ________________ ☐ Cost incurred in last cropping year ________________ ☐ Total number of productive days lost in last cropping year________
12.2. Cholesterol	☐ How long have you been suffering ________________ ☐ Treatments taken- Yes. No ☐ Where did you take the treatment ________________ ☐ Cost incurred in last cropping year ________________ ☐ Total number of productive days lost in last cropping year________
12.3. Asthma	☐ How long have you been suffering ________________ ☐ Treatments taken- Yes. No ☐ Where did you take the treatment ________________ ☐ Cost incurred in last cropping year ________________ ☐ Total number of productive days lost in last cropping year________
12.4. Rheumatoid Arthritis	☐ How long have you been suffering ________________ ☐ Treatments taken- Yes. No ☐ Where did you take the treatment ________________ ☐ Cost incurred in last cropping year ________________ ☐ Total number of productive days lost in last cropping year________
12.5. Skin irritation, pigmentation	☐ How long have you been suffering ________________ ☐ Treatments taken- Yes. No ☐ Where did you take the treatment ________________ ☐ Cost incurred in last cropping year ________________ ☐ Total number of productive days lost in last cropping year________
12.6. Conjunctivitis	☐ How long have you been suffering ________________ ☐ Treatments taken- Yes. No ☐ Where did you take the treatment ________________ ☐ Cost incurred in last cropping year ________________ ☐ Total number of productive days lost in last cropping year________

12.7. Tuberculosis	☐ How long have you been suffering ____ ☐ Treatments taken- Yes. No ☐ Where did you take the treatment ____ ☐ Cost incurred in last cropping year ____ ☐ Total number of productive days lost in last cropping year____
12.8. Chronic cough	☐ How long have you been suffering ____ ☐ Treatments taken- Yes. No ☐ Where did you take the treatment ____ ☐ Cost incurred in last cropping year ____ ☐ Total number of productive days lost in last cropping year____
12.9. Diarrhoea	☐ How long have you been suffering ____ ☐ Treatments taken- Yes. No ☐ Where did you take the treatment ____ ☐ Cost incurred in last cropping year ____ ☐ Total number of productive days lost in last cropping year____
12.10. Kidney disorders	☐ How long have you been suffering ____ ☐ Treatments taken- Yes. No ☐ Where did you take the treatment ____ ☐ Cost incurred in last cropping year ____ ☐ Total number of productive days lost in last cropping year____
12.11. Back pain	☐ How long have you been suffering ____ ☐ Treatments taken- Yes. No ☐ Where did you take the treatment ____ ☐ Cost incurred in last cropping year ____ ☐ Total number of productive days lost in last cropping year____
12.12. Pain in joints	☐ How long have you been suffering ____ ☐ Treatments taken- Yes. No ☐ Where did you take the treatment ____ ☐ Cost incurred in last cropping year ____ ☐ Total number of productive days lost in last cropping year____
12.13. Sleep disorders	☐ How long have you been suffering ____ ☐ Treatments taken- Yes. No ☐ Where did you take the treatment ____ ☐ Cost incurred in last cropping year ____ ☐ Total number of productive days lost in last cropping year____

12.14. Thyroid	☐ How long have you been suffering ________________ ☐ Treatments taken- Yes. No ☐ Where did you take the treatment ________________ ☐ Cost incurred in last cropping year ________________ ☐ Total number of productive days lost in last cropping year________
12.15. Cancer	
12.15.1. Brain cancer	☐ How long have you been suffering ________________ ☐ Treatments taken- Yes. No ☐ Where did you take the treatment ________________ ☐ Cost incurred in last cropping year ________________ ☐ Total number of productive days lost in last cropping year________
12.15.2. Lung Cancer	☐ How long have you been suffering ________________ ☐ Treatments taken- Yes. No ☐ Where did you take the treatment ________________ ☐ Cost incurred in last cropping year ________________ ☐ Total number of productive days lost in last cropping year________
12.15.3. Laryngeal Cancer	☐ How long have you been suffering ________________ ☐ Treatments taken- Yes. No ☐ Where did you take the treatment ________________ ☐ Cost incurred in last cropping year ________________ ☐ Total number of productive days lost in last cropping year________
12.15.4. Prostate Cancer	☐ How long have you been suffering ________________ ☐ Treatments taken- Yes. No ☐ Where did you take the treatment ________________ ☐ Cost incurred in last cropping year ________________ ☐ Total number of productive days lost in last cropping year________
12.15.5. Other types of Cancer (Please specify________)	☐ How long have you been suffering ________________ ☐ Treatments taken- Yes. No ☐ Where did you take the treatment ________________ ☐ Cost incurred in last cropping year ________________ ☐ Total number of productive days lost in last cropping year________
12.16. Any other diseases (Please specify ____________)	☐ How long have you been suffering ________________ ☐ Treatments taken- Yes. No ☐ Where did you take the treatment ________________ ☐ Cost incurred in last cropping year ________________ ☐ Total number of productive days lost in last cropping year________

13. Questions on Changes after APCNF	
13.1. How has your farm changed since the adoption of APCNF? What do you feel are the most important changes? *(Open-ended)*	
13.2. How many crops where cultivated before you adopted APCNF?	______________________ (Nos. of Crops)
13.3. How many crops were cultivated after adopting APCNF?	______________________ (Nos. of Crops)
13.4. Have your costs changed since the adoption of APCNF?	☐ 1. Increase ☐ 2. No change ☐ 3. Decrease
13.5. How do crop yields compare with before you adopted APCNF?	☐ 1. Increase ☐ 2. No change ☐ 3. Decrease
13.6. How has the productivity of farm animal's changes since adopting APCNF?	☐ 1. Increase ☐ 2. No change ☐ 3. Decrease
13.7. How has your farm income changed after adopting APCNF?	☐ 1. Increase ☐ 2. No change ☐ 3. Decrease
13.8. How have your savings changed after adopting APCNF?	☐ 1. Increase ☐ 2. No change ☐ 3. Decrease
13.9. How many cows and buffaloes did you have before beginning APCNF? *(Choose one or multiple options as applicable)*	☐ Cows ______________________ (Number) ☐ Buffaloes ____________________ (Number)

13.10. How has your farm labour use changed since adoption of APCNF?	☐ 1. Increase ☐ 2. No change ☐ 3. Decrease
13.11. What where the fertilizers you used before the adoption of APCNF? State name and amount used.	1.________; ______ (Kg) 2.________; ______ (Kg) 3.________; ______ (Kg) 4.________; ______ (Kg) 5.________; ______ (Kg)
13.12. What where the pesticides you used before the adoption of APCNF? State name and amount used	1.________; ______ (ml) 2.________; ______ (ml) 3.________; ______ (ml) 4.________; ______ (ml) 5.________; ______ (ml)
13.13. How has your expenditure on seeds and hired or bought machinery changed after adopting APCNF?	☐ 1. Increased ☐ 2. No change ☐ 3. Decreased
13.14. How has your expenditure on loans and interest changed after adopting APCNF?	☐ 1. Increased ☐ 2. No change ☐ 3. Decreased ☐ 0. Not applicable
13.15. Have you noticed any changes to your health or the health of your family since adopting APCNF?	☐ Yes ☐ No
13.16. How often did members of your family visit the doctor before you adopted APCNF? (Number of times per year)	__________ (Nos. of Visits per Year)
13.17. What was the annual expenditure on medical care in a year before APCNF?	__________ (Rs./Year)
13.18. How is the food consumption of you and your family changed since the adoption of APCNF?	☐ 1. Increased ☐ 2. No change ☐ 3. Decreased

13.19. Has there been any change in attendance of schools by children since the adoption of APCNF?	☐ 1. Increased ☐ 2. No change ☐ 3. Decreased

14. Cropping Pattern before Adoption of APCNF

14.1. Please mention the year for which the below data is provided: _____ (Year)

Crop Grown (Name)	**Total Area** (Acre / Cent)	**Total cost of cultivation** (Rs)	**Total Income from Crop** (Rs)
1. ___________	_______	_______	_______
2.___________	_______	_______	_______
3.___________	_______	_______	_______
4.___________	_______	_______	_______
5.___________	_______	_______	_______

NOTES

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