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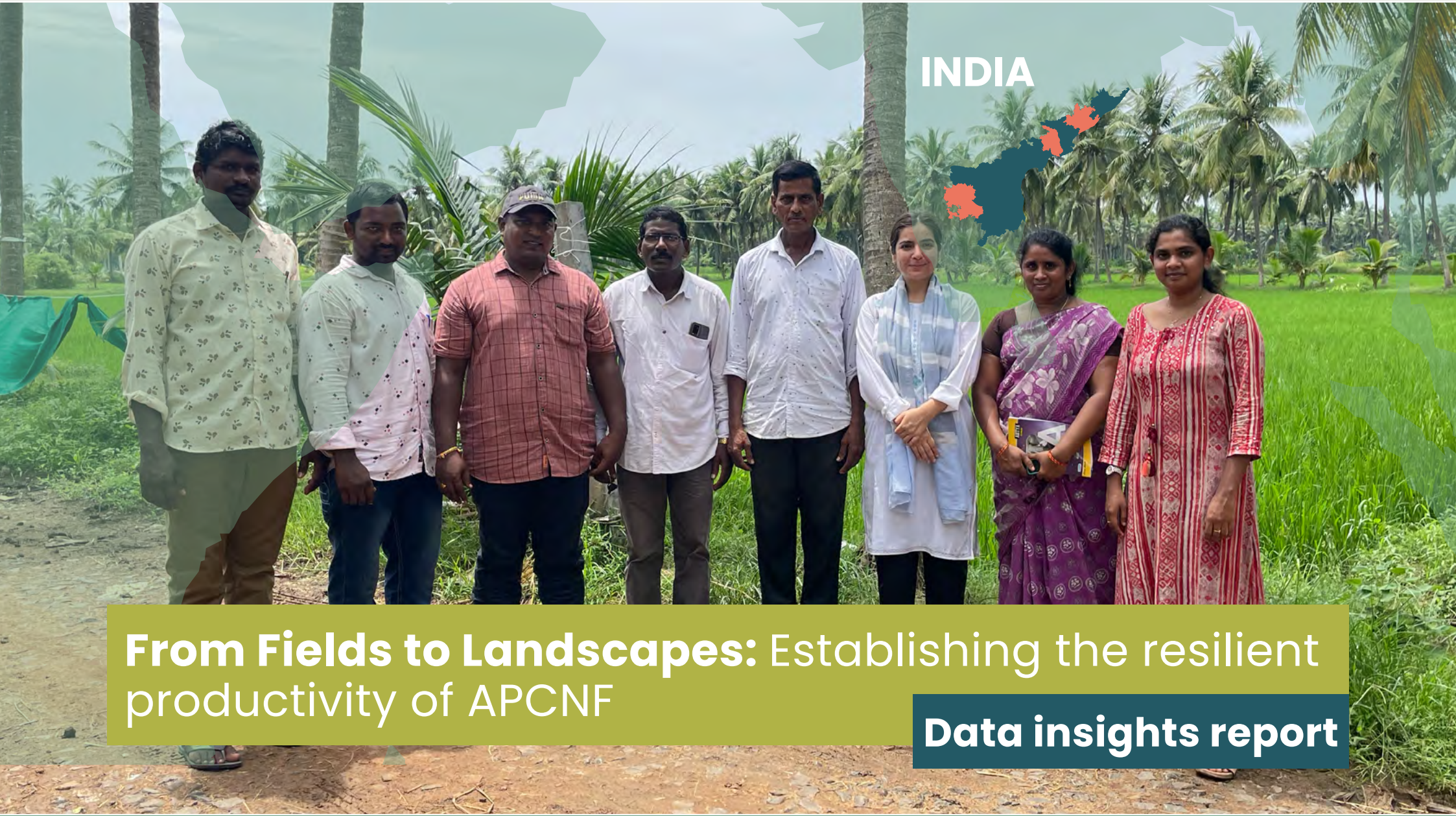

From Fields to Landscapes: Establishing the resilient productivity of APCNF

Data insights report

Acknowledgements

RySS and ICRAF would like to thank the farmers from across Andhra Pradesh (AP) for helping to innovate on the farms and implement the planned comparisons. The participation, extensive expertise and the input from a wide array of stakeholders is critical to the ambitions of the project and wider vision to work at landscape scale to achieve intended impacts from Andhra Pradesh Community Managed Natural Farming (APCNF).

From Fields to Landscapes: Establishing the resilient productivity of APCNF, Data insights report

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Additional project resources

This report forms part of the project outputs - From Fields to Landscapes - Establishing the Resilient Productivity of APCNF.

Project Website

Illustrated Workshop Report (2019)

Exemplar Landscape Report

Stakeholder Mapping Report

Planned Comparison Protocol

Blog on the first engagement landscape workshop in November 2019

Blog on the concept of Engagement Landscapes

Blog on restoring soil and land health in Andhra Pradesh with a landscape approach

Acronyms and abbreviations

APCNF	Andhra Pradesh Community Managed Natural Farming
ASR	Alluri Sitharama Raju
DAP	Di-ammonium phosphate
GGM	*Ghanajeevamrutham*
ICRP	Internal Community Resource Person
JVM	*Jeevamrutham*
MOP	Muriate of potash
PMDS	Pre-monsoon dry sowing
SOC	Soil organic carbon

Contents

Overview

This report aims to provide a synthesis of the data on Andhra Pradesh Community Managed Natural Farming (APCNF) collected within the project: From Fields to Landscapes: Establishing the resilient productivity of APCNF. It provides critical insights to inform policy recommendations and scientific research.

The report covers the following key areas:

Project context - the background and objectives of the project.

Agricultural inputs and practices - the specific farming techniques and advancements employed in the Andhra Pradesh region.

Socio-economic drivers of APCNF - the socio-economic factors that influence the adoption of the APCNF approach.

Drivers and barriers of APCNF adoption - the factors that encourage or hinder the use of APCNF.

Impact of climate change - the adaptation actions that farmers have adopted.

Project Context

Andhra Pradesh, like many states in India, faces severe environmental challenges impacting its agricultural systems. These challenges include declining soil organic carbon (SOC), diminishing plant diversity, loss of above-ground biomass, and increasing water stress. These factors contribute to vast areas of barren land, jeopardizing the state's agricultural resilience.

A SOLUTION: ANDHRA PRADESH COMMUNITY MANAGED NATURAL FARMING

In response to this crisis, the Andhra Pradesh government implemented the APCNF program. APCNF is a holistic approach emphasizing agro-ecological methods for long-term agricultural resilience. Key principles of APCNF include minimal soil disturbance, utilization of bio-stimulants and organic residues, crop diversification, botanical-based pest management, and maintaining year-round soil cover.

PROJECT PURPOSE

This project aims to investigate the effectiveness of APCNF in addressing the environmental challenges faced by Andhra Pradesh's agricultural systems. By evaluating the program's impact on soil health, plant diversity, biomass production, and water usage, we can assess its potential to contribute to a more resilient and sustainable agricultural future for the state. The project adopted a planned comparison approach to measure, track, and assess the impact and performance of APCNF practices across diverse farming contexts within the state.

PLANNED COMPARISON HYPOTHESIS

Natural farming maintains crop yield and reduces climate and health impacts.

State

Andhra Pradesh

Districts

Ananthapuramu, Alluri Sitharama Raju (ASR), and West Godavari.

Sample size

16 villages across 3 districts.

The studied crops

Kharif season crops: cereals, pulses and oil seeds, paddy, castor, tomato, and groundnut.

Rabi season crops: rajma, paddy, and groundnuts.

Timing

Kharif season 2022 and
Rabi season 2022-2023.

SAMPLE SIZE: THE NUMBER OF INTERVIEWED FARMERS PER SEASON, PER DISTRICT FOR THE PLANNED COMPARISON STUDY

Kharif 2022

Farmers
381

West Godavari
84

ASR
116

Ananthapuramu
181

Rabi 2022-2023

Farmers
243

West Godavari
71

ASR
59

Ananthapuramu
117

FARMER SURVEY DATA

Objective of the survey was to:

- To understand the socio-economic characteristics of farmers in the Andhra Pradesh engagement landscape including characteristics of their farms.
- To understand and document the farming practices farmers are implementing on their farms.
- To document farmer innovation around natural farming among the farmers in the engagement landscape.
- To document farmer understanding of climate change and the associated impacts.

Farmers interviewed
1021

West Godavari
418

ASR
331

Ananthapuramu
272

Time of collection
December 2022 - January 2023

***Table 1**. Compared plot types and practices. (*Jeevamrutham - a liquid mix of cow dung, cow urine, water, jaggery, pulse flour and soil; **Ghanajeevamrutham - solid and dried version of Jeevamrutham; ***Kashayams - botanical extracts).*

	 **All basic APCNF practices** seed treatment; *Jeevamrutham**; *Ghanajeevamrutham***	 **Including natural farming practices** *Kashayams****, pre-monsoon dry sowing, biocultures and biofertilizers	 **General practices** mulching and manure	 **Use of chemical inputs** fertilizer and pesticides (herbicides, insecticides)
Full APCNF	✓ Yes	✓ Yes	✓ Yes	✗ No
Partial APCNF	Some	✓ Yes	✓ Yes	✗ No
Non-chemical	✗ No	Some	Some	✗ No
Chemical	✗ No	✗ No	✗ No	✓ Yes
Chemical plus	Some	Some	Some	✓ Yes

CLIMATE CONDITIONS PER DISTRICT

West Godavari

Climate zone
Tropical

Summer
Hot

Winter
Moderate

Rainfall
High

Ananthapuramu

Climate zone
Semi-arid to arid

Summer
Hot and dry

Winter
Hot and dry

Rainfall
Low

ASR

Climate zone
Humid subtropical

Summer
Warm

Winter
Mild

Rainfall
High

Agricultural Inputs and Practices

This section explores the main farming techniques and insights on the practices and inputs used in the Andhra Pradesh region. It analyzes the differences and main trends across the Ananthapuramu, ASR and West Godavari districts.

INSIGHTS ON AGRICULTURAL PRACTICES

Highlighting the strengths: Ananthapuramu had impressive adoption rates in crop rotation (73%) and pre-monsoon dry sowing (PMDS). The benefit of crop rotation is that it keeps soil healthy (nutrients, pests, structure), and reduces reliance on fertilizers. The benefit of PMDS is that farmers can plant their crops earlier, leading to better water use, potentially higher yields, and less soil erosion. West Godavari had a high use (84%) of neem extract, a natural and eco-friendly pest control method.

The challenge: Some practices had low adoption rates such as intercropping (22% or less), mulching (28% or less) and compost manure (15% or less). However, these practices have vital benefits for example, intercropping results in greater yields, better soil, natural pest control, and fewer weeds. Mulching saves water, prevents weed growth, regulates temperature, and adds nutrients to the soil. The use of compost manure boosts soil fertility, improves soil structure, feeds microbes, and reduces fertilizer needs.

Standing out: Ananthapuramu had a unique adoption of the double row sowing method for groundnut, potentially leading to cost-efficiency compared to broadcasting in other districts.

ASR in context: ASR had overall lower adoption rates for APCNF practices compared to the other two districts, but ASR is also the only district where farmers did not apply chemicals and where farmers opted for more distinct crops.

Table 2. *Natural farming practices and inputs used during the 2022 Kharif and 2022-2023 Rabi seasons.*

Practices/ Inputs	Ananthapuramu	ASR	West Godavari
Mulch	28%	2%	11%
Intercropping	22%	6%	1%
Crop rotation	73%	1%	4%
Agroforestry	43%	6%	53%
Compost manure	2%	0%	15%
Neem extract	12%	1%	84%
PMDS	72%	46%	63%
Inorganic fertilizers	32%	1%	38%

Table 2. *Natural farming practices and inputs used during the 2022 Kharif and 2022-2023 Rabi seasons CONTINUED.*

Practices/ Inputs	Ananthapuramu	ASR	West Godavari
Chemical pesticides	47%	2%	35%
Jeevamrutham	98%	95%	58%
Ghanajeevamrutham	72%	95%	46%
Kashayam	79%	74%	53%
Farmyard manure	76%	96%	55%
Biofertilizers	1%	1%	36%
Biocultures	0%	0%	48%

Points for Further Analysis

- Investigate the reasons behind the low adoption rates for certain practices in each district.

- Why are farmers in ASR not utilizing border crops and trees as extensively as those in other districts? These practices could potentially lead to increased yields, along with additional benefits like wind protection, soil conservation, improved water retention, and reduced pest problems. Investigating the reasons behind ASR's lower adoption rate could provide valuable insights for promoting the use of border crops and trees in the district.

- Adoption of compost manure, mulch, and intercropping in all districts was relatively low. Further analysis is needed on why farmers have not adopted these practices.

- The use of neem extract was high in West Godavari. Neem extract use is promoted by RySS and is popular for providing protection to paddy from pests. Moreover, PMDS, agroforestry and border crop/ trees utilization were also high in West Godavari. How could farmers in other districts learn from the benefits observed from implementing these practices in West Godavari.

- Ananatapur had the highest adoption of crop rotation. Further analysis on the benefits of crop rotation in the district, and sharing this knowledge with the other two districts, could be beneficial for scaling up the practice across all districts.

- Ananthapuramu was the only district with a different sowing method. It would be good to have a better understanding of the benefits of the double row sowing method and to share the benefits with farmers in the other districts who use random and broadcasting sowing methods.

OVERVIEW OF INPUTS USED

An interesting insight is that **ASR is the only district** where there were **no chemical plots** and so the practices and inputs used vary immensely from those in Ananthapuramu and West Godavari (see Figures 1 and 2).

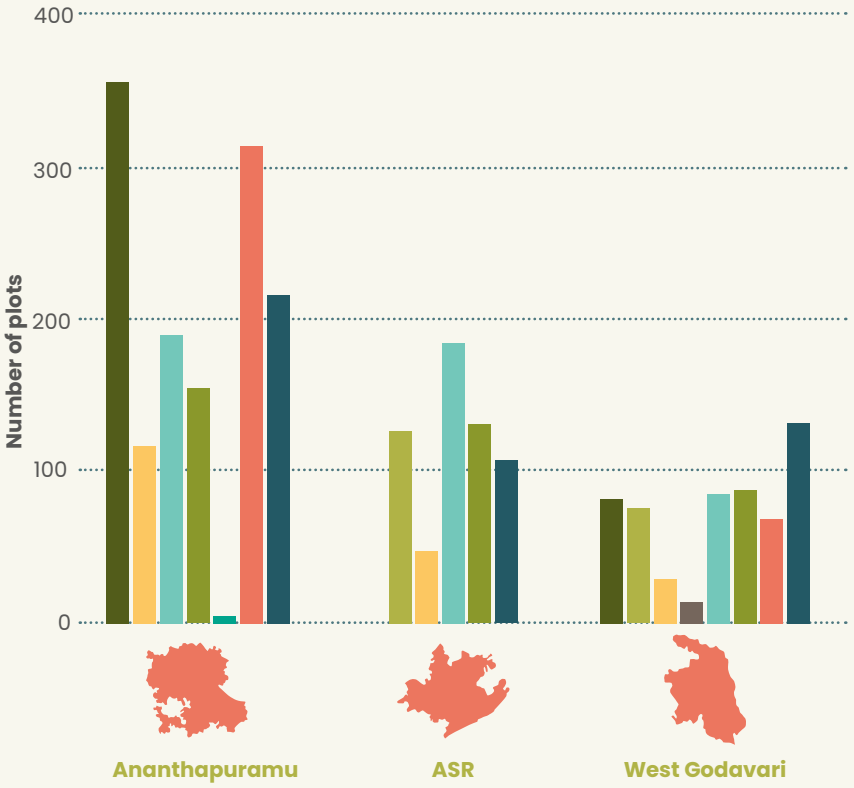

Figure 1. *Inputs used by farmers during the Kharif season.*

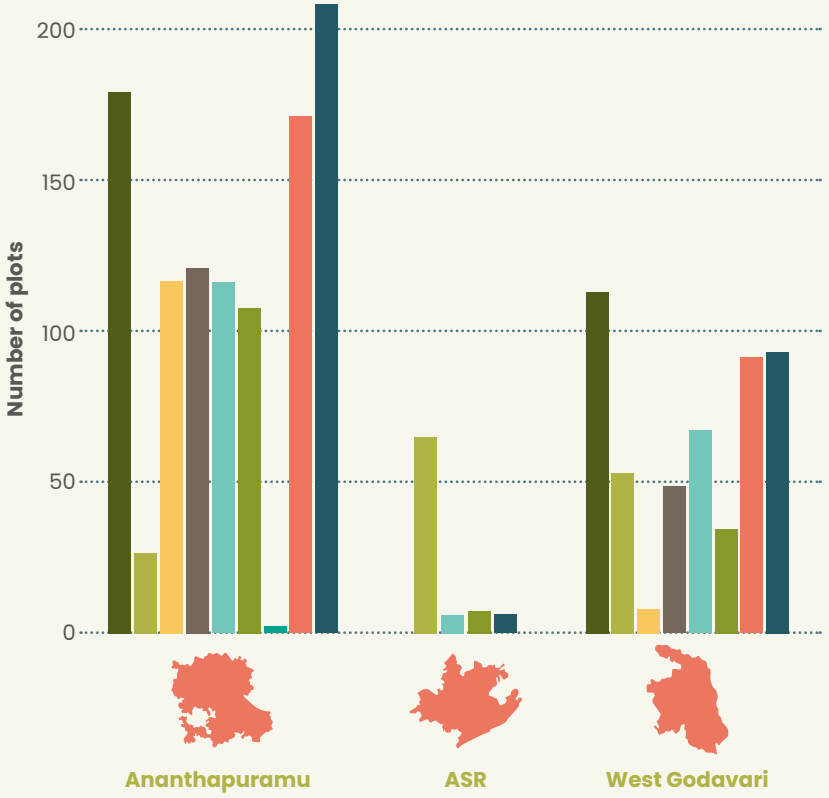

Figure 2. *Inputs used by farmers during the Rabi season.*

INPUT USED

Chemical fertilizers | **Farmyard manure** | ***Ghanajeevamrutham*** | **Herbicides** | ***Jeevamrutham*** | ***Kashayam*** | **Mulching** | **Pesticides** | **Seed treatment**

USE OF SEED TREATMENT PRACTICES ACROSS DISTRICTS

Beejamrutham Tops Seed Treatment Methods: Higher Adoption in West Godavari and APCNF Plots

Across all districts (Ananthapuramu, ASR, and West Godavari) and plot types (APCNF and conventional or chemical), *Beejamrutham* emerged as the preferred seed treatment method. Notably, West Godavari led in adoption with 87%, this is higher than ASR's 39% and Ananthapuramu's 59%. Furthermore, seed treatment appeared more prevalent within APCNF plots compared to chemical plots.

Ananthapuramu

59% of all farmers use seed treatment.

Farmers in Ananthapuramu primarily rely on *Beejamrutham* to treat their seed.

Rabi season: Within APCNF plots, farmers solely used *Beejamrutham*. However, in plots designated as "chemical plus," a combination of *Beejamrutham* and conventional agrochemical-based seed treatments was employed.

ASR

39% of all farmers use seed treatment.

Kharif season: Seed treatment adoption increased in ASR during the Kharif season, with 39% of farmers treating seeds with *Beejamrutham*, again mainly in partial APCNF plots.

Rabi season: Seed treatment was not widely adopted in ASR during the Rabi season. Only 9% of farmers reported treating seeds, and all exclusively within partial APCNF plots (plots utilizing a portion of the Andhra Pradesh Community Nutrient Management Framework). These farmers primarily used *Beejamrutham*, an organic treatment believed to contain beneficial fungi and bacteria that can aid seed growth.

West Godavari

87% of all farmers use seed treatment.

Kharif season: Seed treatment adoption in West Godavari reached 80% during the Kharif season. Interestingly, all farmers who did not treat their seeds belonged to farms designated as "chemical plots." Notably, 100% of farmers used *Beejamrutham*-based treatments. Chemical plus plots had the highest usage of Beejamrutham, followed by partial APCNF plots, with full APCNF plots having the least usage.

Rabi season: Seed treatment was more common in West Godavari during the Rabi season, with 65% of farmers utilizing it. *Beejamrutham* dominated (98%), while a small percentage (2%) used Pseudomonas, another biological seed treatment.

Beejamrutham Points for Further Analysis

- What factors contribute to the higher seed treatment adoption in West Godavari?
- Are there specific benefits associated with using Beejamrutham compared to conventional seed treatments?
- Is there a reason for the lower seed treatment adoption within full APCNF plots in West Godavari?

USE OF *JEEVAMRUTHAM (JVM)*

APCNF plots receive JVM more frequently and in higher quantities during the 2022 Kharif season, except in Ananthapuramu

For most districts and seasons JVM was made by the farmers themselves, except for West Godavari during the Kharif season. Full APCNF plots tended to receive the most frequent applications and highest quantities of JVM. However, Ananthapuramu showed a shift in focus during the Kharif season, when JVM was applied more frequently to chemical plus plots compared to APCNF plots.

Ananthapuramu

98% of the farmers use JVM.

Kharif season: Unlike the Rabi season, most JVM applications in Ananthapuramu during the Kharif season occurred in chemical plus plots. However, when considering quantity, full APCNF plots still saw the highest usage during the Kharif season. The majority of JVM used in Ananthapuramu during the Kharif season was self-produced by the farmers.

Rabi season: JVM usage in Ananthapuramu during the Rabi season was focused on APCNF plots. All full APCNF plots and 90% of partial APCNF plots applied JVM. Interestingly, the highest quantity of JVM was applied in full APCNF plots during the Rabi season. All farmers using JVM in Ananthapuramu during the Rabi season produced it themselves.

ASR

95% of the farmers use JVM.

Kharif season: JVM adoption increased in ASR during the Kharif season, with 58% of farmers utilizing it. The majority (75%) applied it in partial APCNF plots, with an average application frequency of 2 times per plot (with outliers applying it up to 6 times). Similar to the Rabi season, all JVM used in ASR during the Kharif season was self-produced.

Rabi season: Adoption of JVM was low in ASR during the Rabi season, with only 9% of farmers using it exclusively in partial APCNF plots. The application frequency was around 3 times per plot, with an average volume of 741 litres used. Notably, all JVM used in ASR during the Rabi season was self-produced by the farmers.

West Godavari

58% of the farmers use JVM.

Kharif season: JVM adoption in West Godavari during the Kharif season reached 56%, with the majority using it in partial APCNF plots, followed by full APCNF and then chemical plots. Notably, only half of the farmers employed JVM during the Kharif season, primarily in partial and chemical plots. The most frequent application of JVM occurred in full APCNF plots during both the Rabi and Kharif seasons.

Rabi season: In this season, JVM usage was most prevalent with 67% of the chemical plots and 22% of the partial APCNF applying JVM.

Ownership and acquisition: A key difference in West Godavari was the source of JVM. While most JVM was self-produced during the Rabi season, 57% of it was provided by field cadre during the Kharif season.

Jeevamrutham Points for Further Analysis

- What factors contribute to the lower self-production of JVM in West Godavari during the Kharif season?
- Are there specific benefits associated with using JVM in full APCNF plots compared to other plot types?
- Why does Ananthapuramu exhibit a shift in JVM application during the Kharif season?

USE OF *GHANAJEEVAMRUTHAM (GGM)*

APCNF Plots Drive GGM Use: Across all districts limited use of GGM observed

Across all districts and seasons, GGM use was concentrated in full APCNF plots. ASR led in GGM application, while West Godavari used it the least. Interestingly, the source of GGM (owned vs. purchased can vary). Despite this variation, most farmers across districts primarily relied on self-produced GGM.

Ananthapuramu

72% of the farmers use GGM.

Kharif season: During the Kharif season, most GGM applications shifted to chemical plus plots in Ananthapuramu.

Rabi season: GGM adoption in Ananthapuramu was highest during the Rabi season, with 50% of farmers utilizing it. The majority applied it to APCNF plots, with a frequency of once per season. Full APCNF plots saw the most GGM usage in terms of quantity.

ASR

95% of the farmers use GGM.

Kharif season: Only 15% of farmers in ASR applied GGM during the Kharif season, and all exclusively within full APCNF plots. Most of the labor for application was self-provided by the farmers. The application frequency was typically once per season.

West Godavari

46% of the farmers use GGM.

Kharif season: Similar to the Rabi season, few farmers (26%) in West Godavari used GGM during the Kharif season. Among those who did, 75% applied it on full APCNF plots. Notably, full APCNF plots again had the highest GGM use per hectare (1132kg).

Rabi season: Very few farmers (9%) in West Godavari used GGM during the Rabi season. Among those who did, applications occurred once per season. Interestingly, a larger portion (71%) of the GGM used was self-owned, with the remaining 29% purchased.

Ghanajeevamrutham Points for Further Analysis

- Are there specific benefits associated with using GGM in full APCNF plots compared to other plot types?
- Could promoting the use of GGM or exploring cost-effective production methods benefit farmers in all districts?

USE OF *KASHAYAM*

District Variations in *Kashayam* Use: Self-Production vs. Purchase and APCNF Link

Self-produced *Kashayam*, a biopesticide, was the preferred source for farmers in ASR and Ananthapuramu throughout the seasons. However, West Godavari leaned towards purchasing *Kashayam* during the Kharif season.

Interestingly, partial APCNF plots saw the most frequent applications of *Kashayam* across all districts. This suggests a potential link between application frequency and the level of APCNF implementation.

Ananthapuramu presented a unique trend during the Kharif season. Here, the focus for *Kashayam* application shifted from non-chemical and partial APCNF plots to chemical plots. Additionally, West Godavari farmers relied more on field cadre services to obtain Kashayam specifically during the Kharif season, suggesting a possible seasonal change in procurement methods.

Ananthapuramu

79% of the farmers use *Kashayam*.

Kharif season: During the Kharif season, 46% of farmers in Ananthapuramu applied botanical extracts. The frequency of use was highest in non-chemical plots, while the quantity of use was highest in partial APCNF plots. Similar to the Rabi season, all Kashayam used in Ananthapuramu during the Kharif season was self-produced.

Rabi season: *Kashayam* usage in Ananthapuramu during the Rabi season was minimal, especially in chemical plots. However, those that did mostly applied neemastram as the type of *kashayam*. Notably, full APCNF plots saw the highest frequency and quantity of application. All *kashayams* used in Ananthapuramu during the Rabi season was self-produced by the farmers.

ASR

74% of the farmers use *Kashayam*.

Kharif season: *Kashayam* adoption increased to 46% in ASR during the Kharif season. Application primarily occurred in partial APCNF plots. Two types were used: *Bhramastram* and *Agnistram*. The application frequency drops to once per season on average. Interestingly, 63% of the *Kashayam* used in ASR during the Kharif season was self-produced.

Rabi season: Adoption of *Kashayam* was low in ASR during the Rabi season, with only 11% of farmers applying it. *Neemastram* and *Agnistram* were the primary types used. The application frequency ranged from 2 to 3 times, with an average volume of 370.5 litres per hectare. All *Kashayam* used in ASR during the Rabi season was self-produced by the farmers.

West Godavari

53% of the farmers used *Kashayam*.

Kharif season: *Kashayam* adoption nearly doubled in West Godavari during the Kharif season to 58%. The majority (58%) was applied on partial APCNF plots, followed by chemical plots (24%). The median application amount was three litres, with the highest usage observed in partial APCNF plots. Notably, farmers used *Kashayam* twice on average during both seasons. However, during the Kharif season, they tended to rely more on field cadre services to obtain *Kashayam*, JVM, and GGM.

Rabi season: The majority (76%) of farmers in West Godavari during the Rabi season did not apply *Kashayam*. Chemical plus plots had the highest application rate among those who did use it.

Kashayam Points for Further Analysis

- What factors contribute to the lower self-production of *Kashayam* in West Godavari during the Kharif season?
- Are there specific benefits associated with using *Kashayam* in partial APCNF plots compared to other plot types?

USE OF FARMYARD MANURE

Farmyard Manure Dominates: ASR Leads in use, Compost Manure use in some Districts

ASR stood out as the district with the highest overall use of farmyard manure throughout both seasons. Notably, self-ownership of this manure was the dominant practice across all districts and seasons. While a small portion of farmers in West Godavari purchased farmyard manure during the Kharif season, self-production remained the norm. Interestingly, in ASR and West Godavari, farmyard manure seemed to be favored for plots that avoided inorganic fertilizers. This suggests a potential synergy between farmyard manure use and organic farming practices within APCNF systems in these districts.

Ananthapuramu

76% of farmers in Ananthapuramu use farmyard manure.

Rabi season: During the Rabi season, only 17% of farmers applied farmyard manure. Interestingly, only chemical plus plots, and even then, just a small percentage of farmers within those plots used it.

ASR

98% of the farmers use farmyard manure.

Kharif season: Farmyard manure adoption remained high in ASR, with 55% of farmers applying it. Nearly all (99%) of the farmyard manure used was self-owned. Application typically occurred once per season, with all labor for its application being self-provided by the farmers.

Rabi season: The use of farmyard manure was highest in ASR with 53% of farmers using it and 91% applying it on plots that didn't use inorganic fertilizers. The remaining usage was distributed between full and partial APCNF plots. Notably, all farmers applying farmyard manure in ASR during the Rabi season used their own sources.

West Godavari

55% of the farmers use farmyard manure.

Kharif season: Farmyard manure adoption increased in West Godavari during the Kharif season to 50%. Here, 43.4% was applied on partial APCNF plots and 35.5% on plots that use a combination of inorganic fertilizers and farmyard manure. Interestingly, 84% of the farmyard manure used in West Godavari during the Kharif season was self-owned, with the remaining portion purchased.

Rabi season: In West Godavari during the Rabi season, 40% of farmers applied farmyard manure. The majority (77%) was used on plots that use a combination of inorganic fertilizers and farmyard manure, with the remaining 21% used on partial APCNF plots. All farmyard manure used in West Godavari during the Rabi season was self-owned by the farmers.

Farmyard manure Points for Further Analysis

- What factors contribute to the high popularity of farmyard manure?
- Why is farmyard manure adopted at a higher rate than compost manure?

USE OF GROWTH PROMOTERS

Low Growth Promoter Use: *Panchagavya* in Ananthapuramu and Egg Amino Acids for Intensive Plots in West Godavari

Across all the districts surveyed, the adoption of growth promoters remained low, with less than 15% of farmers utilizing them. In Ananthapuramu, only 10% of farmers employed Panchgacya, primarily on plots implementing partial or full APCNF systems. West Godavari showed a slightly higher adoption rate of 15%, with egg amino acids being the favored choice. Interestingly, their use was concentrated on plots considered intensive, such as full APCNF and chemical plus plots. This suggests a potential link between growth promoter use and more intensive farming practices in West Godavari.

Ananthapuramu

Only **10%** of the farmers applied growth promoters on their farms during the **Rabi season** and this was mostly on partial and full APCNF plots. The type of growth promoter used is *Panchagavya*.

ASR

No use

West Godavari

Only **15%** of farmers used growth promoters, and the majority applied egg amino acids. Growth promoters were used once and primarily on full APCNF, partial APCNF or chemical plus plots. The highest volumes were applied on full APCNF and chemical plus plots.

Growth promoters Points for Further Analysis

- What are the reasons for the low adoption of growth promoters?
- What is the effectiveness of the different promoter types?
- What are the optimal application rates and timings for different crops in each of the districts?
- What are the costs and benefits of the practice to the farmers?

USE OF BIOCULTURES AND BIOFERTILIZERS

Lack of Bio-Inputs: Minimal Use in All Districts Calls for APCNF Exploration

During the Rabi season, the adoption of both biofertilizers and biocultures remained very low across all districts. In Ananthapuramu and ASR, farmers didn't utilize biocultures or biofertilizers at all during this season. West Godavari presented a slight exception, with 40% of farmers applying biocultures primarily on chemical plus plots. However, the use of biofertilizers remained very low, with only 4% of farmers adopting this practice. This minimal adoption across the board suggests a need for further investigation into the potential benefits and implementation strategies for biocultures and biofertilizers within APCNF systems.

Ananthapuramu

Both biocultures and biofertilizers are almost entirely not used.

ASR

Both biocultures and biofertilizers are almost entirely not used.

West Godavari

48% of all the farmers applied bioculture and **36%** applied biofertilizers.

Biocultures and Biofertilizers Points for Further Analysis

- What are the reasons for the low adoption rate of biocultures and biofertilizers across all districts?
- What are the potential benefits of integrating biocultures and biofertilizers into APCNF systems?
- How cost-effective are bio-agents in comparison to conventional methods?

USE OF INORGANIC FERTILIZERS

Contrasting Fertilizer Strategies: Ananthapuramu Relies on Chemicals, West Godavari Adapts Across Seasons in chemical and Chemical Plus Plots

Compared to West Godavari, Ananthapuramu relied heavily on inorganic fertilizers throughout the year. Here, farmers prioritized a balanced application of urea, muriate of potash (MOP), and di-ammonium phosphate (DAP), with higher quantities used on chemical plus plots.

On the other hand, West Godavari exhibited a more nuanced approach. While fertilizer use was common, it dipped during the Kharif season. Interestingly, the farmers' consistent use of urea, MOP, and DAP reflects an awareness of the importance of NPK nutrients.

Ananthapuramu

32% of the farmers use inorganic fertilizers.

Kharif season: Inorganic fertilizer use was high in Ananthapuramu during the Kharif season, with 98% of farmers using it in chemical and chemical plus plots.

Rabi season: Inorganic fertilizer use was prominent in Ananthapuramu during the Rabi season with 76% of farmers applying it in chemical and chemical plus plot. Three main fertilizers, urea, MOP, and DAP were used in relatively equal proportions. The application frequency leaned towards twice per season for a majority (63%) of farmers. The median quantity of fertilizer applied during the Rabi season was around 170kg, with higher quantities observed in chemical plus plots.

ASR

1% of the farmers use inorganic fertilizers. In ASR, none of the farmers who took part in the planned comparisons applied inorganic fertilizers during the Kharif and Rabi seasons.

West Godavari

41% of the farmers use inorganic fertilizers.

Kharif season: Inorganic fertilizer use dipped in West Godavari during the Kharif season, with only 54% of farmers utilizing it.

Rabi season: Inorganic fertilizer use was common in West Godavari, with 82% of farmers applying it during the Rabi season in chemical and chemical plus plots. The primary fertilizers used were urea, MOP, and DAP.

Inorganic fertilizer Points for Further Analysis

- Are there specific factors influencing the higher inorganic fertilizer use in Ananthapuramu compared to West Godavari?
- Could promoting best practices for bio fertilizer application improve efficiency and potentially reduce chemical fertilizer usage?

USE OF CHEMICAL PESTICIDES

Pesticide Reliance Varies: Ananthapuramu Sprays Heavily Year-Round, West Godavari Shifts Seasonally

Ananthapuramu stood out for its substantial use of chemical pesticides across both seasons especially in chemical plus plots. Typically, applications occured twice per season, with an average usage of 1.54 litres per hectare applied during the Rabi season. In contrast, West Godavari revealed a seasonal trend. Here, farmers relied more heavily on chemical pesticides during the Rabi season compared to the Kharif season. This variation between districts suggests a need to explore the factors driving pesticide use patterns across different areas.

Ananthapuramu

47% of the farmers use chemical pesticides.

Kharif season: Chemical pesticide use increased further in Ananthapuramu during the Kharif season, with 87% of farmers applying them in chemical and chemical plus plots.

Rabi season: Chemical pesticide use was high in Ananthapuramu during the Rabi season, with 73% of farmers applying them. Notably, most users applied them in chemical plus plots. The application frequency leaned towards twice per season for a majority (67%) of farmers. The average quantity of pesticide applied per hectare during the Rabi season was 1.54 litres.

ASR

2% of the farmers use chemical pesticides. In ASR, none of the farmers who took part in the planned comparisons applied chemical pesticides during the Kharif and Rabi seasons.

West Godavari

35% of the farmers use chemical pesticides.

Kharif season: Chemical pesticide use dipped in West Godavari during the Kharif season, with only 45% of farmers using them.

Rabi season: In West Godavari, chemical pesticide use was more frequent in the Rabi season with 66% of farmers applying them.

Chemical pesticides
Points for Further Analysis

- Are there specific pest threats driving the higher chemical pesticide use in Ananthapuramu?
- Can alternative bio pest control methods be explored to reduce dependence on chemical pesticides in both districts?

Socio-economic Drivers of APCNF

This section examines the social and economic factors that influence the adoption of the APCNF approaches by the farmers in Andhra Pradesh.

SOCIAL DRIVERS

Agricultural Resilience: Insights into Land Size Dynamics and Adaptive Decisions

With an average farm size of only 1.1 ha and a predominance of marginal farmers (94%), land resources are scarce. This limited space can restrict the adoption of practices like APCNF. Since every hectare counts, there is limited space for experimentation with practices like APCNF, which can require more land for initial implementation.

Table 3. *Land size groups of the surveyed APCNF households.*

Land Size Group	Marginal (0>1ha)	Small (1-2ha)	Medium (2-4ha)	Large (≥4ha)
Total households	929	29	13	19
Percentage (%)	94%	3%	1%	2%
Average land size	0.20 ha	1.20 ha	2.02 ha	20.24 ha
Standard deviation	0.199	0.247	0.370	7.862

Driving APCNF Adoption Through Knowledge and Advocacy

The majority of respondents from the surveyed households lacked formal schooling. Out of all the farmers surveyed, 32% (322 farmers) had primary-level education (1–6 years of schooling), 18% had secondary-level education, and only 14% had tertiary-level education (more than 12 years).

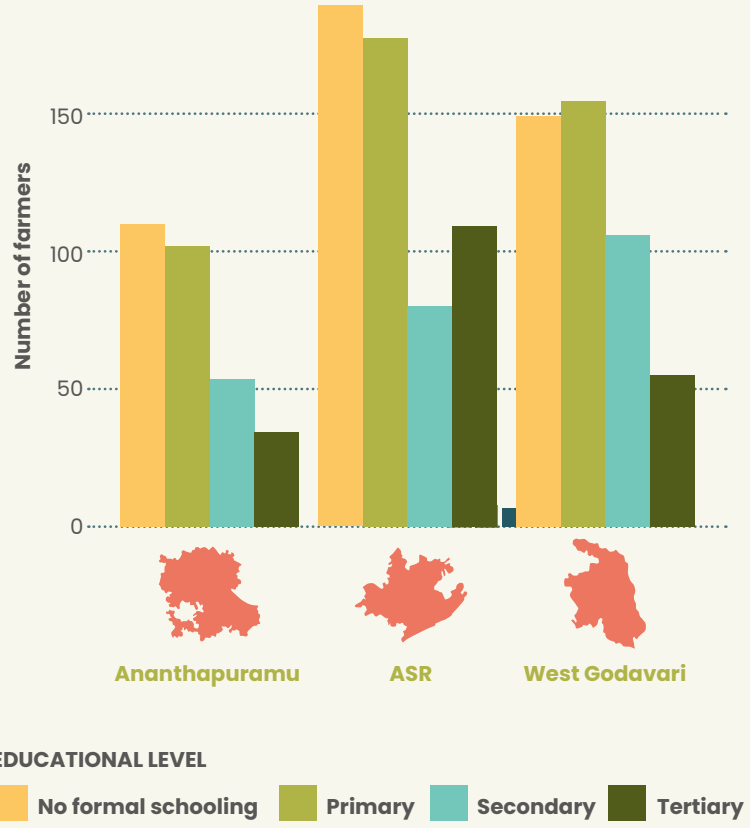

Figure 3. *Farmers' education levels according to district.*

Age and Gender Influence on Adoption of APCNF Practices

The average age of farmers may influence their openness to new practices like APCNF. Older farmers, with their wealth of experience and traditional knowledge, may resist change. On the other hand, younger farmers might be more receptive but lack the practical skills for effective implementation. Interestingly, the data from Andhra Pradesh shows an average farmer age of 44 (see Figure 4), potentially positioning them to benefit from both traditional knowledge and a willingness to adapt.

For the most part, interviewed households in the three districts had male household heads (85%). Most of the interviewed farmers were also male (Figure 5). However, the number of farmers attending APCNF training sessions varied across the districts. In ASR, there were 64 male participants and 19 female participants. In Ananthapuramu, the numbers shifted slightly with 78 male attendees and 88 female attendees. However, in West Godavari, the attendance was predominantly male, with 94 male participants and only 5 female participants.

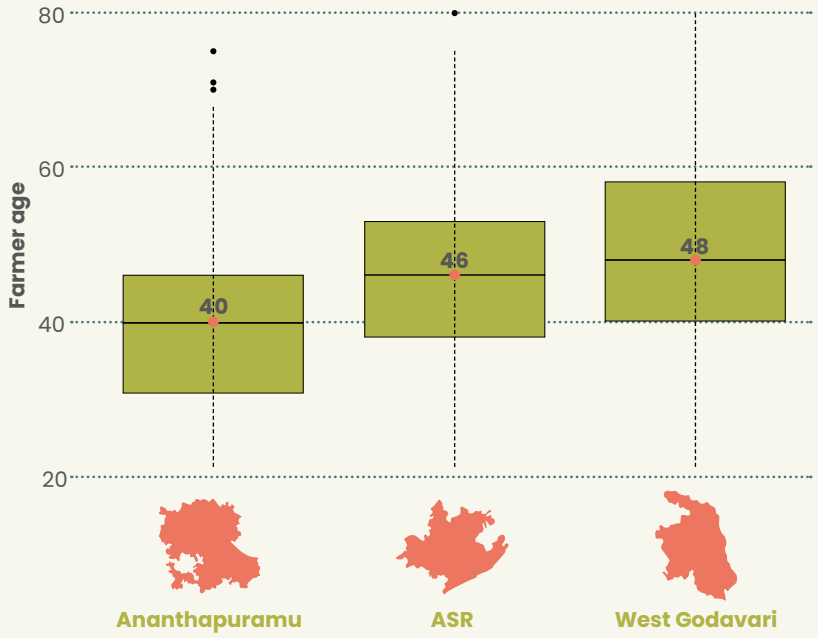

Figure 4. *Age of farmers (in years) according to the district.*

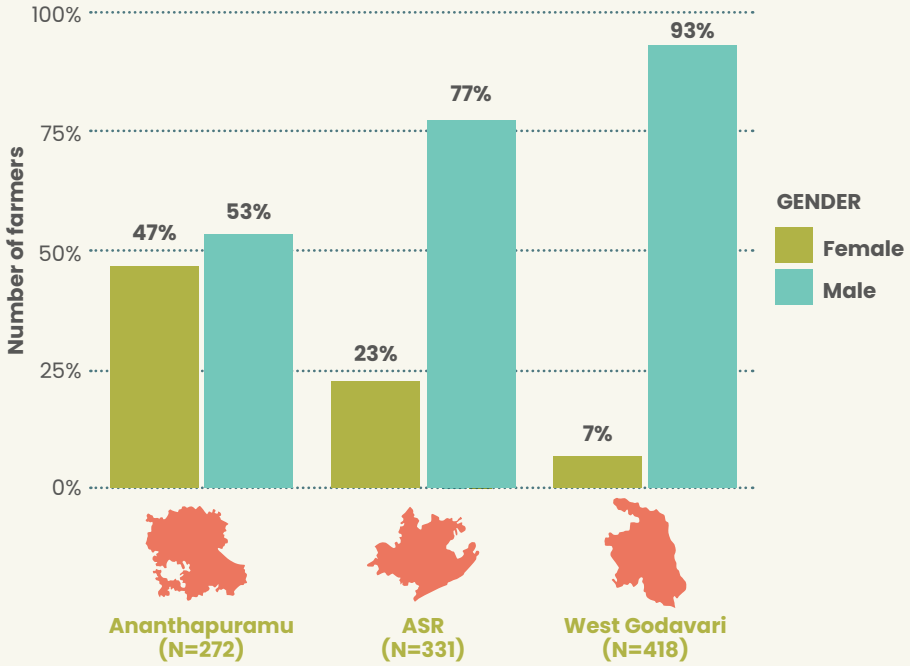

Figure 5. *Gender of interviewed farmers according to the district.*

Farm Ownership Fuels APCNF Adoption

The survey indicated that 74% of all the farms in Andhra Pradesh were owned by the farmers themselves, reflecting a strong sense of ownership and autonomy. This ownership status can foster the adoption and implementation of APCNF practices, as farmers are more inclined to invest in long-term sustainability and innovation on their own land. Furthermore, land ownership grants farmers greater control over decision-making processes, enabling flexible experimentation and adaptation of new farming techniques.

Table 4. *Land ownership types of the surveyed households.*

Land ownership type	Own	Rented	Tribal	Other (leased)
Number of farmers	753	230	1	37
Percentage of farmers	74%	23%	0%	3%

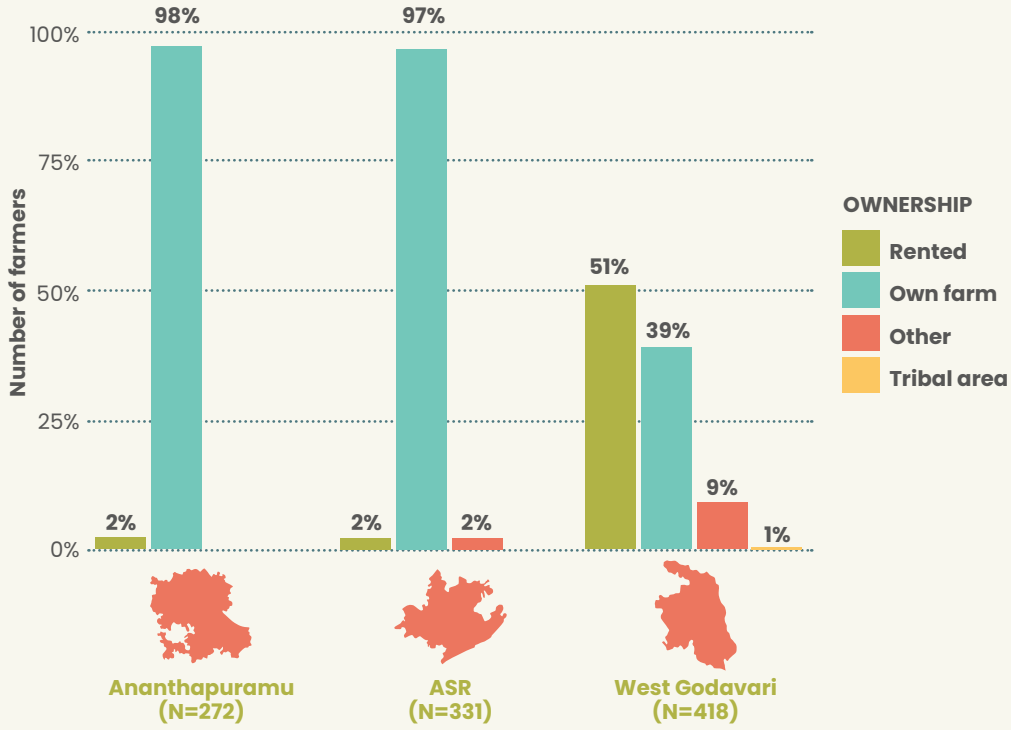

Figure 6. *Land ownership types according to district.*

Land ownership varied across the three districts. Almost all the farms in ASR (97%) and Ananthapuramu (98%) were owned by farmers, whereas around half of the farms (51%) in West Godavari were rented.

ECONOMIC DRIVERS

Full APCNF: Higher Input Costs Across Districts

A clear trend emerged when examining input costs across different farming methods and districts (see Figures 7 and 8). The chosen option (Full APCNF, partial APCNF, chemical and chemical plus) along with the specific district considerably impacted the overall cost. In general, during the the Kharif season, chemical plus plots had the highest average cost of purchasing inputs per hectare. In comparison, the cost of purchasing inputs increased considerably during the Rabi season particularly in the chemical plots. Notably, average input cost per hectare for APCNF plots during the Kharif season was minimal and increased slightly during the Rabi season.

Ananthapuramu

During the Kharif season, full APCNF and chemical plus plots had the highest input costs. In the Rabi season, full APCNF plots showed the highest input costs. However, it is worth noting that the input cost for APCNF plots included the cost of purchasing the raw materials and preparing the inputs. This suggests that APCNF methods in Ananthapuramu might have higher upfront investment needs compared to conventional chemical farming.

ASR

For the Kharif season, it was observed that APCNF had the highest input costs. In the Rabi season, the partial APCNF plot had the highest input costs.

West Godavari

In the Kharif season, chemical plus plots had the highest input costs. This trend continued in the Rabi season with conventional chemical plots leading in input costs.

Points for Further Analysis

- Analyze the yield and profit margins across different farming methods and districts to understand the cost-benefit trade-off for each approach.
- Investigate the specific components driving the higher input costs in full APCNF plots, in Ananthapuramu (e.g., cost of raw materials, labor for on-farm preparation).
- Explore potential government subsidies or market incentives that could encourage the adoption of full APCNF practices.

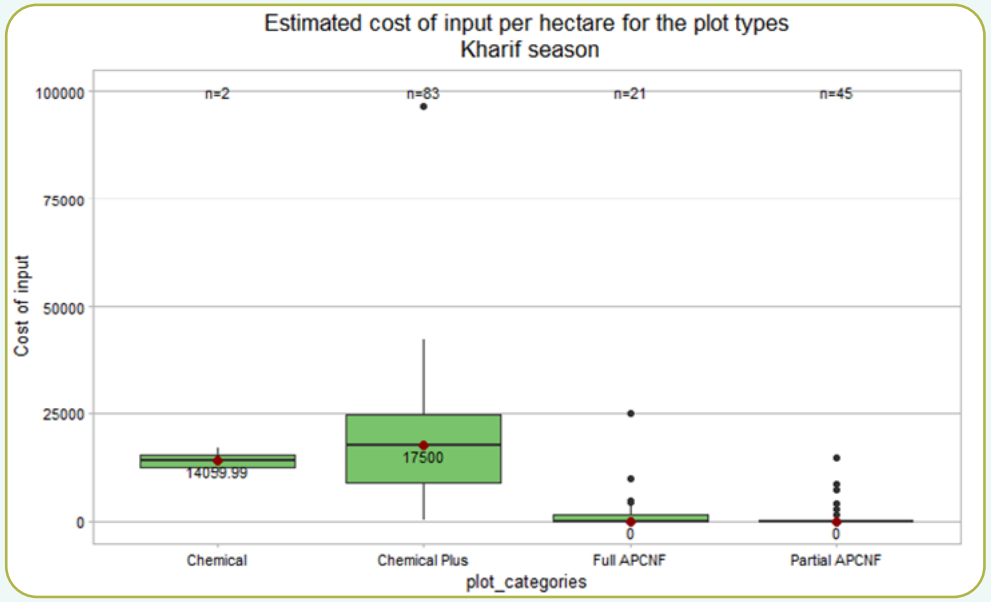

Figure 7. *Estimated cost of inputs per hectare during the Kharif season.*

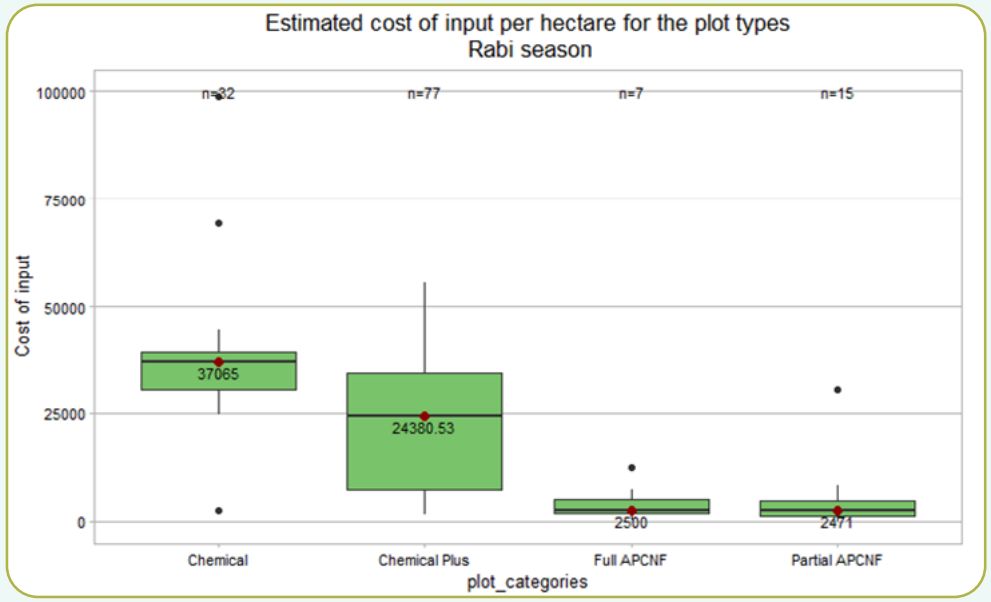

Figure 8. *Estimated cost of inputs per hectare during the Rabi season.*

APCNF LABOR COSTS AND RELIANCE ON HIRED LABOR

Partial and full APCNF plots generally incurred higher labor costs, particularly during land preparation, compared to non-chemical, chemical plus and chemical plots. This likely stems from the increased use of manual techniques and organic inputs that require more labor for application.

However, the picture is not black and white. **The source of labour (own or hired) can differ by district and season**. Different seasons necessitate various preparation activities, potentially influencing the need for additional hired workers.

For instance, analyzing Figure 9 and 10 reveals that across all districts, farmers relied to some extent on hired labor specifically for land preparation during the Rabi season. This suggests particularly labor-intensive tasks within APCNF practices.

Land preparation stands out further when compared to other farm activities in terms of labor source. Farmers appear to utilize hired labor more frequently for this activity compared to tasks performed with their own workforce (see Figure 10).

Ananthapuramu

Labor preparation costs in Ananthapuramu were higher for non-chemical, full APCNF and partial APCNF plots compared to chemical plots during the Rabi season. This suggests that organic and semi-organic farming methods in Ananthapuramu might require more labor input during land preparation. Additionally, Ananthapuramu shows a high rate in hired labor for land preparation compared to ASR and West Godavari.

ASR

The average land labor cost was 600 rupees and costs were highest in full APCNF plots compared to other plots. Moreover, the ASR district had non-chemical plots, and during the Rabi season, all labor for land preparation was owned. The Kharif season shows variation, with a majority of the labor owned but some hired as well. This could indicate a more self-sufficient approach to labor management in ASR, especially for organic farming practices.

West Godavari

During the Rabi season, West Godavari saw a high reliance on owned labor (85%) across all farming methods. However, full APCNF plots incurred the highest overall labor costs, followed by partial APCNF plots. This could indicate that while West Godavari farms rely on own labor for farm activities, organic and semi-organic practices of land preparation within the district may be more labor-intensive. Notably, during land preparation most of the labor was hired (see Figure 10).

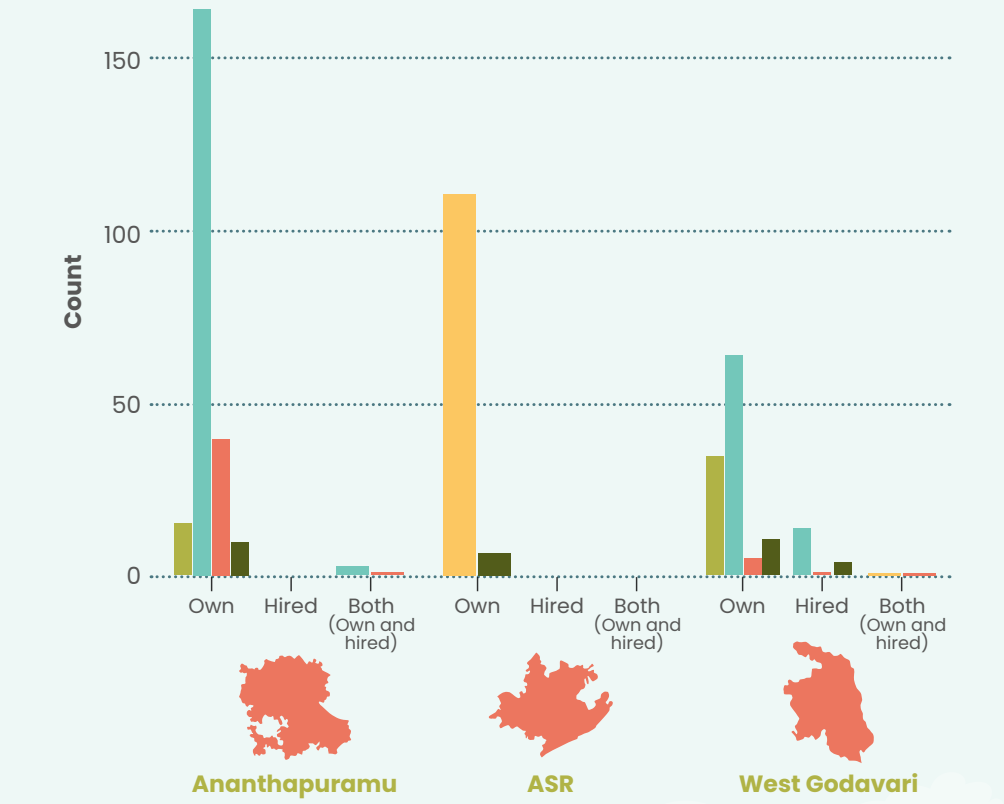

Figure 9. *Source of labour used for preparing and applying natural farming inputs during the Rabi season.*

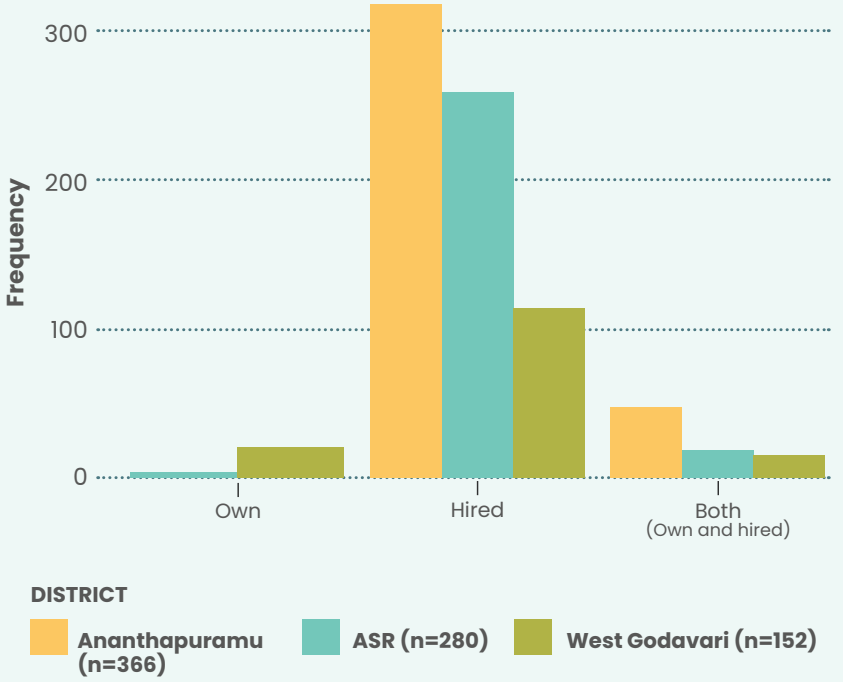

Figure 10. *Source of labour for land preparation according to district.*

APCNF PRODUCE SALES AND MARKETING

Limited Marketing Issues, Premium Pricing is the Hurdle for Some Farmers

Most of the interviewed farmers mentioned that they did not face marketing and sales challenges because their products were sold to regular markets or used for their own consumption. However, the farmers who faced challenges in selling their produce struggled mainly with poor pricing for APCNF produce and lack of marketing support.

Ananthapuramu

Most of the APCNF produce was sold to the regular market with 87% of farmers able to access markets for their produce. Thirty-nine farmers faced marketing challenges including pricing of their goods, proper marketing support, and finding the right market for higher profits.

ASR

In ASR, 66% of the farmers mentioned that most of the APCNF produce is for their own consumption. All the farmers (100%) in ASR did not mention facing any any marketing challenges.

West Godavari

Most of the APCNF produce was for own consumption. Almost all farmers who owned chemical plots sold their produce to others. Most farmers who owned chemical plus, partial and full APCNF plots used the APCNF produce for their own consumption. Most farmers (87%) did not face any challenges in finding a market for their produce. However, 57 farmers had marketing challenges including pricing of their goods, proper marketing support, and finding the right market.

YIELD PERFORMANCE DEPENDS ON CROP AND LOCATION

Yield performance is dependent upon the crop type, its location. For instance, in Ananthapuramu, analyzing dry weight suggests potential benefits for groundnuts under full APCNF implementation and for castor seeds under partial APCNF. On the other hand, ASR witnessed the highest dry weight yields for paddy in full APCNF plots. West Godavari presents a contrasting picture, where full APCNF and chemical plots out performed others in terms of dry paddy weight. These findings highlight the context-dependent nature of optimal farming approaches for yield. Chemical plots might show a general lead, but APCNF systems can outperform in specific scenarios, particularly for certain crops and locations. This underlines the importance of developing location and crop-specific recommendations to maximize yield potential within APCNF farming systems.

Points for Further Analysis

- Can specific APCNF practices be optimized to enhance yields for certain crops?

Ananthapuramu

- Extrapolated data suggests higher average crop yield (kg/hectare) in chemical plots for all crops.
- Dry weight analysis for Kharif season:
  - Full APCNF plots yielded higher weights (kgs/ha) for groundnuts.
  - Partial APCNF plots yielded higher weights (kgs/ha) for castor seeds.
- Dry weight analysis for the Rabi season:
  - Chemical plots yielded higher weights (Kgs/ha) for groundnuts.

Alluri Sitharama Raju (ASR)

Dry weight analysis for the Rabi season: Partial APCNF plots yielded the highest weight (kgs/ha) for paddy.

West Godavari

Dry weight analysis for Kharif season: Both full APCNF and chemical plots yielded the highest weights (kgs/ha) for paddy.

Dry weight analysis for the Rabi season: Full APCNF plots yielded the highest weight (kgs/ha) for paddy.

Drivers and Barriers of APCNF Adoption

DRIVERS OF APCNF ADOPTION IN ANANTHAPURAMU: COST, COMPARISON, AND THE REASONS TO REDUCE CHEMICAL USE

Some farmers highlighted positive experiences with APCNF in Ananthapuramu:

- **Promotion from natural farming meetings:** Exposure to natural farming principles through meetings encouraged adoption.
- **Internal Community Resource Person (ICRP) recommendations:** The endorsement of natural farming methods by the ICRP added credibility.
- **Improved crop quality and soil health:** Farmers reported experiencing positive outcomes like better crop quality and improved soil health after using APCNF methods.

Some farmers also mentioned reasons for reducing or avoiding chemicals in Ananthapuramu:

- **Dedicated natural farming plots:** Certain plots were specifically dedicated to natural farming practices.
- **Chemical input cost concerns:** The expense of some chemicals was a deterrent.
- **Comparative analysis:** Some farmers used chemical plots for comparison with their natural farming plots using the planned comparison approach.
- **Lower pest incidence:** Reduced pest problems were observed in fields with lower chemical use.
- **Effectiveness of neem-based pest control:** The success of neem-based controls (*Neemastram*) offered a natural alternative for pest management.

BARRIERS TO APCNF ADOPTION IN ANANTHAPURAMU: TIME, MATERIALS, AND KNOWLEDGE GAPS

Despite the benefits, farmers in Ananthapuramu identified several challenges hindering their adoption of APCNF practices:

- **Time-consuming input preparation:** Farmers perceived a need for significant time investment to prepare natural farm inputs.
- **Large material quantities:** The perceived need for vast quantities of raw materials for natural inputs can be discouraging.
- **Limited raw material availability:** Concerns exist regarding insufficient local availability of raw materials for input preparation.
- **Participation in APCNF trainings:** 37% of the farmers have not attended the trainings. Most farmers have attended two trainings in the last three years.
- **Participation in APCNF Farmer Field School:** 74% of farmers have not participated.
- **Information sharing among farmers:** Only 25% of farmers have shared information on APCNF with other farmers.

Other farmers in Ananthapuramu mentioned that they use chemical inputs because:

- **Rapid pest control:** Chemicals offer immediate solutions for pest problems.
- **Additional crop nutrition:** Farmers perceive chemical inputs as a source of additional nutrients for their crops.
- **Perceived soil health benefits:** Some farmers believe chemicals contribute to improved soil health.
- **Quicker results:** The perceived speed of action with chemicals can be appealing.

DRIVERS OF APCNF ADOPTION IN ASR: POSITIVE EXPERIENCES AND RESULTS FUEL APCNF CURIOSITY

- **Experimentation with natural methods:** Some farmers expressed a desire to explore natural farming practices and assess their effectiveness.
- **Positive experiences with organic matter:** Prior use of farmyard manure for an extended period suggests openness to organic approaches.
- **Promising results:** Existing examples of successful APCNF practices with good yields can motivate others to adopt these methods.

BARRIERS TO APCNF ADOPTION IN ASR: TIME, KNOWLEDGE, RESOURCES

- **Pre-existing practices:** Some farmers already avoid chemicals or any external inputs, making the adoption of APCNF less relevant.
- **Time constraints:** Farmers expressed concerns about the time investment required for APCNF practices.
- **Knowledge gap:** A lack of understanding regarding APCNF preparation methods was identified as a barrier.
- **Limited human resources:** Farmers perceive a need for additional support and knowledge building through human resources.
- **Participation in APCNF trainings:** Most (67%) of the farmers had not attended the trainings. Most farmers had attended three trainings in the last three years.
- **Participation in APCNF Farmer Field School:** Most (69%) of the farmers had not participated.
- **Information sharing among farmers:** Only 37% of farmers had shared information on APCNF with other farmers.

DRIVERS OF APCNF ADOPTION IN WEST GODAVARI: HEALTHY SOILS, HEALTHY YIELDS

Some positive experiences with APCNF were observed:

- **Yield improvement:** A portion of farmers using APCNF methods reported experiencing good yields.
- **Reduced pest incidence:** Some farmers observed a decrease in pest problems in their APCNF plots.
- **Increased earthworm population:** An increase in earthworm population was observed in some APCNF plots, indicating potential improvement in soil health.

BARRIERS TO APCNF ADOPTION IN WEST GODAVARI: BEYOND WEATHER AND ADDRESSING RISKS

- **Discouragement due to weather uncertainty:** Farmers face general agricultural uncertainties due to weather patterns. This discourages them from adopting potentially complex APCNF practices, leading them to seek simpler solutions like chemical inputs for faster results.
- **Limited risk taking capacity of tenant farmers:** The prevalence of tenant farming in the district suggests a lower risk taking capacity among farmers. Support mechanisms are needed to encourage experimentation with APCNF practices.
- **Mindset shift required for self-sufficiency:** A shift in mindset is needed for farmers to become self-sufficient in practicing APCNF methods on their own. A high dependancy on field cadres for procuring inputs was observed in West Godavar.
- **Participation in APCNF trainings:** Most (69%) of the farmers had not attended the trainings. Most farmers have attended two trainings in the last three years.
- **Participation in APCNF Farmer field school:** Half of the farmers (50%) had not participated.
- **Information sharing among farmers:** Only 27% of farmers had shared information on APCNF with other farmers.

CHALLENGES FACED BY CHEMICAL INPUT USERS

Despite using chemical inputs, some farmers in West Godavari still encountered challenges during the Rabi season:

- **Pest and disease issues:** Farmers reported experiencing issues like stem rots, sheath blights, neck and nodal blasts, yellow stem borers, and crop lodging.
- **Chemical-based solutions:** To address these challenges, farmers resorted to using bio-cultures, spraying pesticides, and additional chemicals on their plots.

OTHER OBSERVATIONS

- Most farmers did not report any noticeable changes in their plots, regardless of the methods used.
- Among those who observed positive changes, a higher proportion were from chemical plus plots. (Further investigation might be needed to understand this finding.)

Impact of Climate Change

Farmers' perceptions of climate change, particularly temperature and precipitation fluctuations, along with past experiences with extreme weather events like floods and droughts, heavily influence their adaptation strategies.

This is evident from the data collected across the three districts, where farmers reported varying observations about weather changes over the past decade.

A significant finding is the widespread occurrence of reduced crop yield across all three districts. This decline in productivity can likely be attributed to various climatic factors, including changes in temperature and precipitation patterns. Farmers predominantly reported reduced yields as the key impact of climate change.

Interestingly, in West Godavari district, farmers additionally identified reduced soil moisture as a significant climate change impact. This highlights the localized nature of climate change, where variations in environmental conditions influence farmers' perceptions and adaptation priorities.

Table 5. Farmers' perception, observation, and adaptation practices to climate change.

Location	Percentage of farmers reporting, experiencing, or noticing changes in weather patterns	Noticed or experienced weather change		Observed effect on crops	Adaptation practices
Ananthapuramu 	68%	37% - Flooding due to heavy rainfall	25% - Low rainfall	Reduced crop yield	• Trenching • Farm pond construction • Rainwater harvesting • Irrigation • Soil and water conservation • ***Drought-tolerant crops***
ASR 	99%	33% Erratic rainfall	26% - Low rainfall	Reduced crop yield	• Trenching • Farm pond construction • Rainwater harvesting • Irrigation • Soil and water conservation
West Godavari 	27%	44% Increasing temperature	44% Increasing temperature	Reduced crop yield	• Rainwater harvesting • Irrigation • ***Use of fertilizers and organic input***

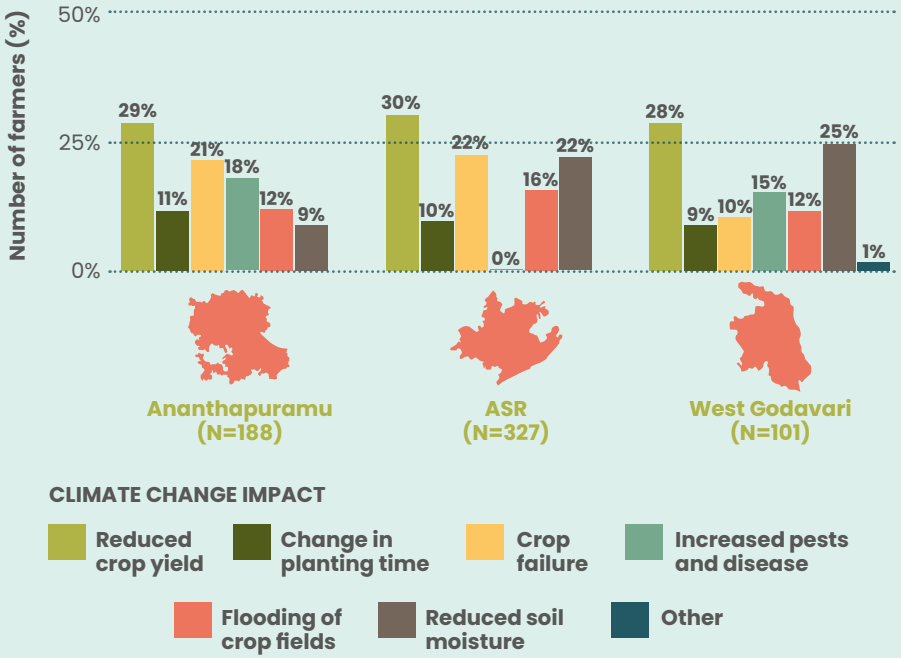

Figure 11. *Impacts of climate change on agriculture.*

TAILORED RESPONSES TO CLIMATE CHANGE: VARIATION ACROSS DISTRICTS

Farmers in ASR, Ananthapuramu, and West Godavari districts adapted to perceived climate shifts in unique ways, highlighting the importance of localized solutions. These districts showcase diverse adaptation strategies, with farmers often employing a combination of approaches such as agroforestry, use of drought resilience plants, rainwater harvesting, irrigation, soil and water conservation, use of organic inputs and fertilizers and the use of intercropping systems. See Figure 12 for detailed practices adopted in each of the districts.

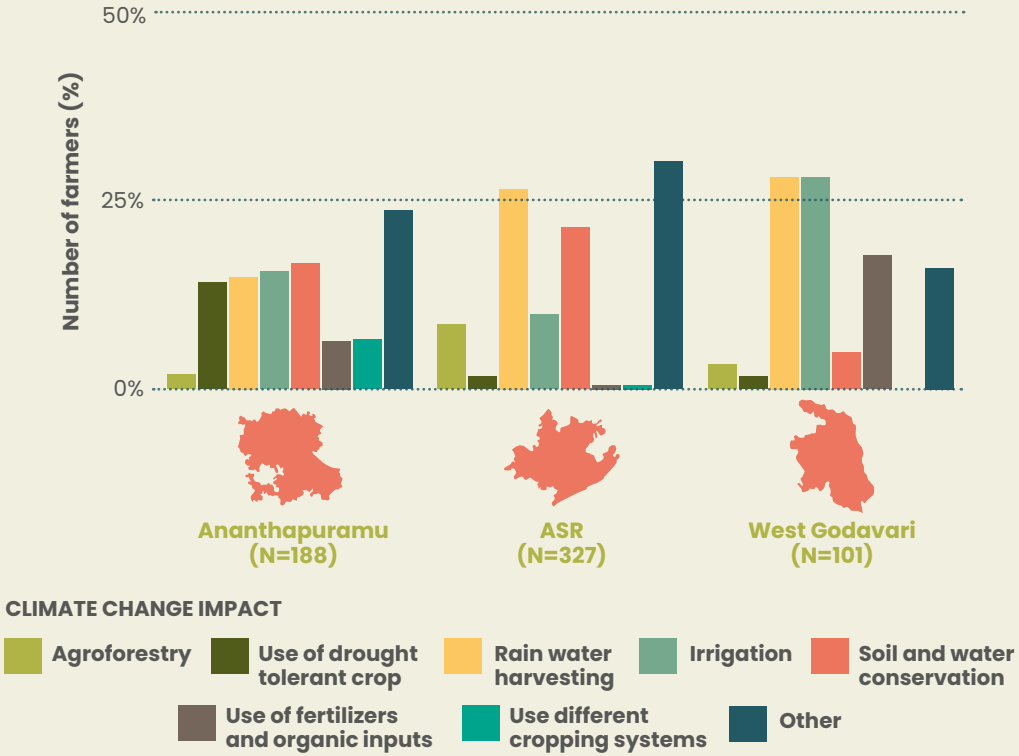

Figure 12. *Modifications made by farmers in the different districts to combat climate change.*

Ananthapuramu

Of all the APCNF practices, soil and water conservation were the most adopted, followed by irrigation practices.

ASR

Rain and water harvesting practices were the most common, followed by soil and water conservation.

West Godavari

Irrigation and rainwater harvesting were the most adopted practices, followed by the use of fertilizers and organic inputs.

LONG-TERM IMPACT OF APCNF ON CLIMATE RESILIENCE

While the APCNF program offers solutions to drought, reduced soil moisture, and crop failure, data reveals that not all farmers adopted key practices that directly address these issues. A practice like agroforestry, which helps retain moisture and combat drought, was not as widely adopted (see Figure 12). Understanding this gap is essential. As mentioned in 'The Drivers and Barriers of APCNF' chapter, other factors such as time, resource limitations, and labor constraints might be barriers for some farmers to adopt certain practices.

While some see immediate benefits like improved yields and soil health, APCNF's true potential unfolds over time. A long-term simulations (1993-2023) of the impact of soil organic carbon (SOC) on rice production in West Godavari and ASR sites highlights the downsides of chemical fertilizers.[1] Overuse of chemical fertilizers on chemical plus farms leads to low nitrogen efficiency, disrupting the soil ecosystem. This is evident in Figures 13a and b where the actual yields (green bars) clearly indicate nutrient inefficiencies in the current production systems at both sites, especially at the West Godavari site. However, long-term simulations of grain yield response to nitrogen (orange bars) show that the nitrogen response can increase under improved crop and soil management, as in the case of partial and full APCNF practices. Further, under the chemical plus treatment, 0 N/ha yields on average are below 1 t/ha whereas under the partial and full APCNF practices they are 1.6 and 2 t/ha, respectively. These higher yields at 0N are attributed to improved soil health built by residue retention and manure application over time.

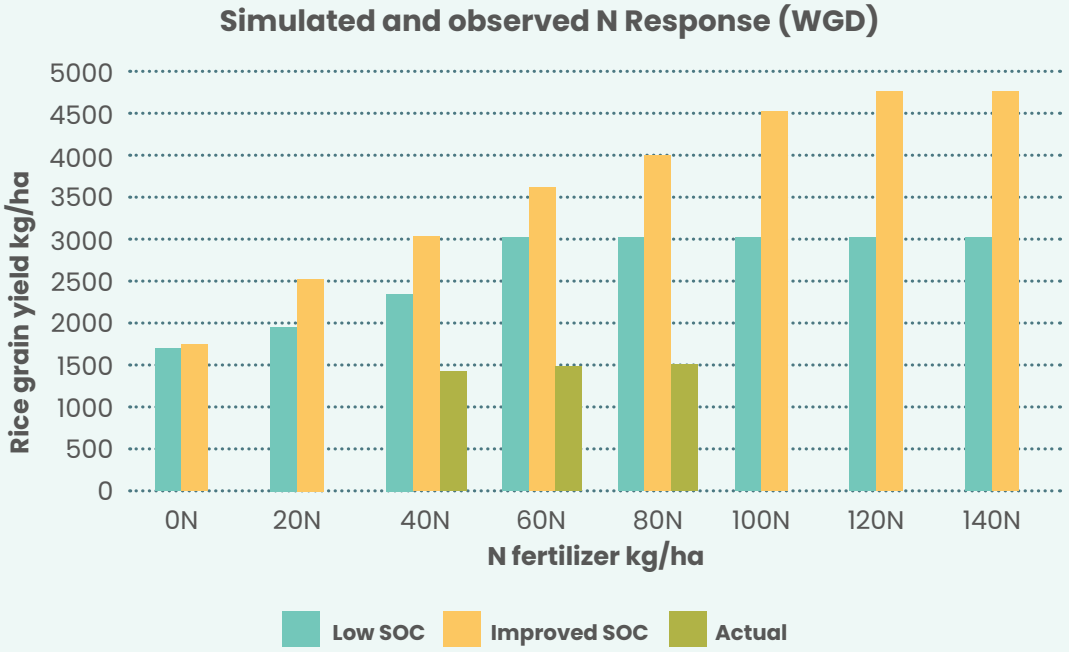

Figure 13a. *Nitrogen (N) response curve for grain yields with blue bars showing the response under current management practices, the orange bars showing the response under improved management systems and the green bars showing actual yields across fertility treatments for the West Godavari site. The first green bar represents the partial APCNF treatment while the second and third green bars represent the chemical-plus and full APCNF practices, respectively.*

1. Patricia Masikati. (2024). Understanding Potential Environmental Benefits of Natural Farming in Andhra Pradesh: Ex-ante analysis.

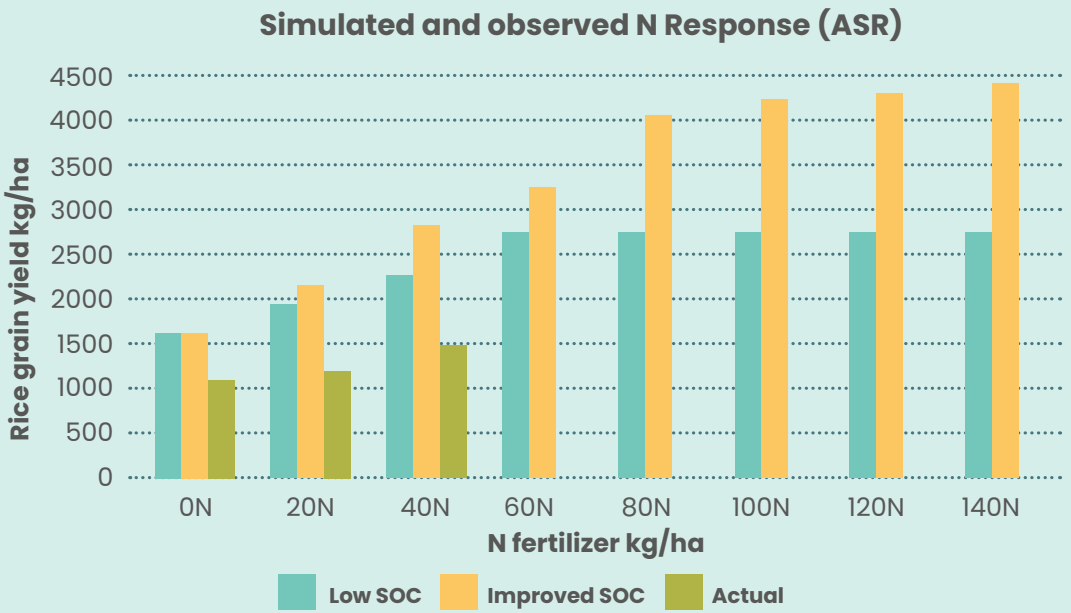

Figure 13b. *Nitrogen (N) response curve for grain yields with blue bars showing response under current management practices, orange bars showing response under improved management systems, and the green bars showing actual yields across the fertility treatments for the ASR site. The first green bar represents the non-chemical treatment while the second and third green bars are for partial and full APCNF practices, respectively.*

APCNF practices like applying manure significantly increase SOC levels which translates to better soil fertility, reduced dependence on chemicals, and increased yield performance. These practices also improve soil moisture and temperature stability, crucial factors for building climate resilience in agriculture. Thirty-year (1993 – 2023) simulations for rice grain yield variability under the full APCNF, partial APCNF and chemical plus practices across the West Godavari and ASR sites clearly indicate the importance of soil health (see Figures 14a and b). Improved soil health through residue retention and manure application under the full and partial APCNF practices produce greater rice yields over time than the chemical plus treatment for both sites. This means that in the long-term, farmers using sustainable management practices can potentially realize higher yields and greater resilience against environmental and climate-related stresses.

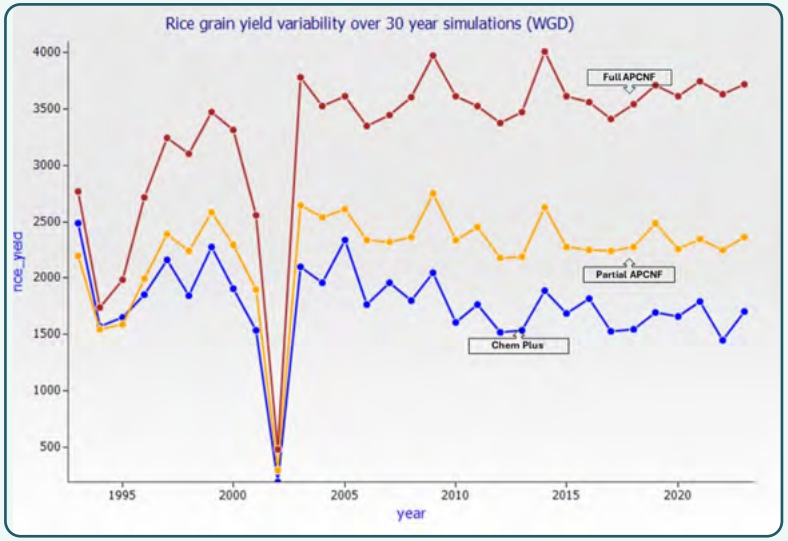

Figure 14a*. Long-term (30-year) simulations on rice grain yield stability for the West Godavari site with no resets of soil organic carbon, nitrogen and water across the three fertility treatments.*

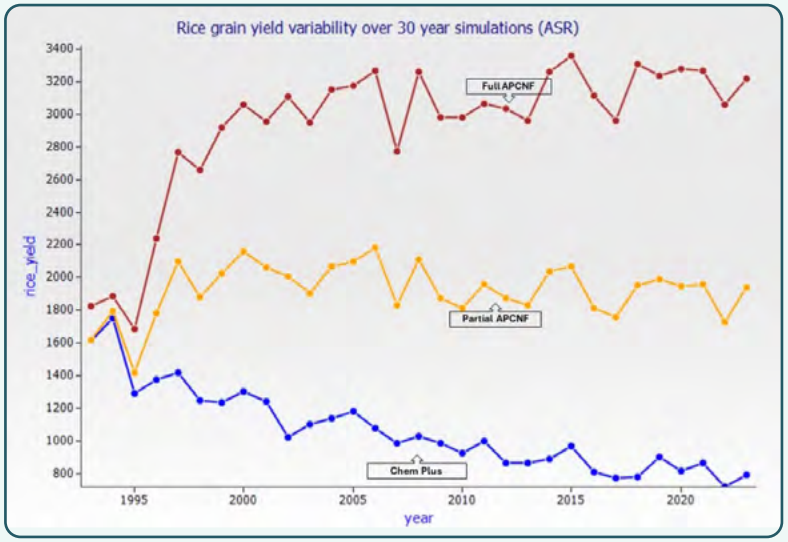

Figure 14b*. Long-term (30-year) simulations on rice grain yield stability for the ASR site with no resets of soil organic carbon, nitrogen and water across the three fertility treatments.*


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