Project Report

Comprehensive Project on Rice-Fallow Management (2023-2024)

February 2025

Submitted to
Directorate of Agriculture & Food Production
Department of Agriculture & Farmers' Empowerment
Government of Odisha

ICRISAT
INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS
Transforming Dryland Agriculture

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Executive Summary

The Comprehensive Project on Rice-Fallow Management (CPRFM) in Odisha continues to exploit the potential of rice-fallow lands for the production of pulses and oilseeds. The project focuses on promoting short-duration and climate-resilient varieties of green gram, black gram, chickpea, lentil, and mustard, leveraging residual soil moisture to optimize yields. GIS-based mapping and remote sensing technology is used to identify suitable areas for intervention, ensuring efficient targeting. Farmers received high-quality seeds of improved varieties and other critical inputs, alongside training on advanced agricultural practices and other crop management systems.

Beneficiary farmers reported cultivating 46.1% of their agricultural land in *Rabi*, significantly higher than control (27.8%) with considerable yield improvements in green gram (214.8 kg/acre, +28.1%), black gram (248.4 kg/acre, +32.7%), mustard (344.0 kg/acre, +33.9%), chickpea (279.2 kg/acre, +34.9%), and lentil (215.2 kg/acre, +35.3%), compared to control groups. Non-beneficiary farmers from the project villages, also recorded yield gains, with productivity increase of up to 13.7%. A comparative analysis between short-duration and longer-duration traditional varieties of green gram and black gram across land types revealed that short-duration varieties performed best in midlands and uplands, where black gram yielded 258.3 kg/acre and greengram 224.9 kg/acre in mid & upland ecology, outperforming their respective yields in lowlands (214.4 kg/acre for black gram and 190.6 kg/acre for green gram). On the other hand, chickpea and mustard were more suitable for lowlands, where they recorded higher yields compared to midlands and uplands. This underlines the need for a targeted dissemination of short-duration varieties in mid and upland rice fallow ecosystems through detailed area characterization using earth science approaches.

Farm incomes improved by ₹5,570 per acre; 62.3% higher than control farmers (₹3,432 per acre). The intervention improved household diets with fewer cases of poor dietary diversity among the beneficiaries as compared to control groups, proving its effectiveness in enhancing nutrition. For every 10 beneficiary families, at least one family has access to a balanced, nutritious diet compared to the control group, proving the intervention's success in improving food security. The Dietary Diversity Index (DDI) analysis revealed significant improvements in household diet and nutrition among beneficiaries. The proportion of households with low dietary diversity was substantially lower among beneficiaries (13.5%) compared to control-1 (24.0%) and control-2 (21.6%) groups. Conversely, households with high dietary diversity were more prevalent among beneficiaries (17.7%) compared to control-1 (11.8%) and control-2 (13.8%). The majority of households fell within the medium dietary diversity category (67.0%), with the highest share observed among beneficiary households (68.8%). These findings suggest that improved agricultural productivity, income enhancement, and access to nutrition-sensitive agricultural practices contributed to dietary diversity improvements. Beneficiaries achieved a per capita pulse consumption of 41.5g/day, surpassing the Indian Council of Medical Research's (ICMR) recommended intake of 40g/day, while women beneficiaries recorded higher Minimum Dietary Diversity Scores (MDD-W) at 78.7%, reflecting better nutritional access. Women-headed households with access to education reported more yield as well as economic gains likely due to better decisions taken on farm management and effective use of inputs.

The analysis identified midland areas as the most suitable for *Rabi* area expansion particularly for the short duration crop varieties, owing their better suitability. The integration of GIS-based mapping and Analytics for Decision Making and Agricultural Policy Transformation (ADAPT) tools enabled precise targeting and real-time monitoring, ensuring efficient intervention delivery. Beneficiary farmers sold 40.6% of their harvest as compared to 33% by control. This shift in beneficiary behavior highlights the intervention's role in transitioning farmers towards commercial, market-oriented agriculture. To sustain the program's impact, strengthening local seed systems is crucial, as 60% of control farmers rely on village markets for seeds, and 27.1% primarily use farm-saved seeds, limiting access to improved varieties and affecting productivity. Expanding the role of Farmer Producer Organizations (FPOs) and cooperatives at local level will be critical for ensuring timely seed availability and reducing dependency on informal seed markets. To ensure long-term productivity, resilience, and farmer profitability, it is crucial to strengthen local seed networks, enhance input supply chains, and improve market linkages, enabling farmers to transition toward a more sustainable and market-driven agricultural system.

1. Project Background

The rice-fallow ecology, prevalent across South Asia, presents both a challenge and an opportunity in the region's agricultural landscape. These lands, covering approximately 14.6 million hectares, remain uncropped during the *Rabi* (winter) season following *Kharif* (monsoon) paddy cultivation. India alone accounts for 80% of this area, with a significant portion located in the Eastern Plateau region - spanning Odisha, Jharkhand, Chhattisgarh, Bihar, and West Bengal. Odisha contributes to 8.5% of India's total rice area and 7% of the national rice production (2022-23). However, a substantial portion of its paddy lands remains fallow during winter, limiting agricultural productivity, food security, and rural incomes.

Despite the potential for intensification, rice fallows remain underutilized due to multiple agro-climatic and socio-economic constraints. Climatic challenges, such as inadequate post-monsoon rainfall, early monsoon withdrawal, and the dominance of long-duration rice varieties, lead to severe soil moisture stress in November and December, making *Rabi* cultivation difficult. Infrastructure limitations, including insufficient irrigation facilities such as canals, pumps, and wells, further restrict cropping options. Socio-economic barriers – such as high input costs, damage from stray cattle, and limited mechanization - discourage smallholder farmers from cultivating a second crop. Additionally, market and policy challenges, including limited access to high-quality seeds, credit, and formal markets, hinder the adoption of improved cropping systems.

Emerging agricultural innovations provide viable pathways to overcome these challenges. The introduction of short-duration pulses and oilseed varieties, specifically bred to leverage residual soil moisture, presents an effective low-input, high-impact strategy. These crops not only enhance soil health but also align with sustainable agriculture, contributing to climate resilience and long-term productivity. Their cultivation directly supports multiple Sustainable Development Goals (SDGs), including SDG 2 (Zero Hunger), SDG 13 (Climate Action), and SDG 15 (Life on Land). Moreover, their adoption benefits smallholder farmers, including women, supporting SDG 1 (No Poverty) and SDG 5 (Gender Equality) while promoting sustainable production systems (SDG 12).

Recognizing the untapped potential of rice fallows, the Directorate of Agriculture and Farmers' Empowerment (DA&FE), Government of Odisha, in collaboration with ICRISAT, other CGIAR institutes, M S Swaminathan Research Foundation (MSSRF), and local NGOs, launched the Comprehensive Project on Rice-Fallow Management (CPRFM). ICRISAT in collaboration with DA&FE piloted the project in Koraput district (5,000 ha) during 2022-23, demonstrating higher productivity and farm incomes through the adoption of short-duration pulses and oilseeds. Encouraged by the pilot's success, the initiative was scaled up in 2023-24, covering 93,850 ha across eight districts of Odisha. The major objectives of the project include promoting short-duration pulses and oilseed crops in rice fallows, strengthening input supply chains, enhancing farmer capacity through participatory demonstrations and training, and utilizing GIS-based mapping for precision targeting.

By integrating scientific advancements with farmer-driven solutions, the project aims to increase pulse production by 20-30%, enhance soil fertility, and raise farmer incomes by 30-40%. Additionally, the intervention focuses on strengthening market linkages, promoting commercial seed systems, and expanding the role of Farmer Producer Organizations (FPOs) to ensure timely seed availability. These efforts will help reduce dependence on informal seed markets and strengthen local input supply chains.

The Comprehensive Rice-Fallow Management (CRFM) Project serves as a scalable model for other underutilized rice-fallow ecosystems across India and beyond. The initiative has demonstrated the potential for transforming rice-fallow areas into productive ecosystems, ultimately contributing to higher incomes, improved food security, and enhanced resilience for farmers in Odisha. The lessons learned from this intervention provide evidence-based recommendations for state and national policies aimed at improving food security, climate resilience, and rural livelihoods.

2. Project Implementation

The Comprehensive Project on Rice-Fallow Management (CPRFM) 2023-24 was designed to unlock the productive potential of 400,000 hectares of rice-fallow lands in Odisha, with ICRISAT leading the implementation across 93,850 hectares in eight districts. The initiative aimed to scale up short-duration pulses and oilseed varieties to address the challenges of underutilized rice fallows and climate variability. By promoting sustainable agricultural intensification, the project sought to enhance food and nutritional security while driving socio-economic development in farming communities.

A data-driven approach was central to the project's implementation. Geographic Information System (GIS) and remote sensing technologies were employed to identify suitable rice-fallow clusters for demonstrations of short-duration pulses and oilseeds. This precision mapping provided accurate insights into the geographical characteristics of rice-fallow lands. Complementing these technological tools, ICRISAT collaborated with local NGOs, leveraging their in-depth regional expertise. These partnerships played a crucial role in the on-ground identification of intervention areas and beneficiaries, in consultation with district agriculture officials. This synergistic approach maximized the utilization of residual soil moisture in previously uncultivated lands during the *Rabi* season.

The project maintained a strong collaborative framework with district and block-level agricultural officers and the local administration throughout the cropping season. Regular engagement with local NGO partners ensured seamless coordination, rapid problem resolution, and effective dissemination of technical knowledge to farmers. This robust network facilitated the timely distribution of critical inputs, reinforcing the project's overall impact.

To enhance data management and monitoring, ICRISAT leveraged ADAPT, a web-based beneficiary registration tool developed and maintained by the Department of Agriculture and Farmers Empowerment, Government of Odisha. This system enabled comprehensive data collection, including beneficiary registration, input distribution records, and technical data on crop management and yields. The ADAPT-DSS emerged as a critical tool, enabling real-time progress tracking and data-driven decision-making, further strengthening the project's operational success.

By integrating advanced technologies, local expertise, and robust data management systems, CPRFM demonstrated a transformative model for converting rice-fallow lands into productive ecosystems. The initiative not only proved the feasibility of sustainable intensification but also laid the groundwork for scaling these interventions across Odisha and similar agro-ecological regions.

2.1 Geography and Socio-Economy of Target Districts

The CPRFM was strategically introduced across all 30 districts of Odisha by the Directorate of Agriculture and Farmers' Empowerment, Government of Odisha. However, ICRISAT led the scientific implementation of the initiative focused on eight key districts to integrate research-driven technologies and maximize project impact.

The selection of target districts was based on their diverse agro-climatic and socio-economic characteristics, ensuring that interventions were tailored to local conditions for optimal scalability. The selected districts of Bargarh, Deogarh, Ganjam, Jharsuguda, Kalahandi, Koraput, Nabarangpur and Sambalpur represent a microcosm of Odisha's agricultural landscape, encompassing varied topographies, soil types, rainfall patterns, and farming systems.

2.1.1. Geographical Characteristics

The target districts exhibit significant geographical diversity, ranging from the fertile alluvial plains of Bargarh and Sambalpur to the undulating terrains of Deogarh and the hilly red soil regions of Koraput and Nabarangpur. Annual rainfall varies between 1,200 mm and 1,600 mm, providing ample opportunities for agricultural intensification, however due to undulated topography, there is a huge water loss due to run off. The irrigation coverage remains limited, making residual soil moisture a crucial factor for *Rabi* crop cultivation in most districts. This necessitates the promotion of short-duration, climate-smart pulses and oilseed crops to optimize land use.

Table 1: Geographical Characteristics of Target Districts under CPRFM, 2023–24

District	Latitude	Longitude	Topography	Soil Type	Rainfall (mm/year)	Average Temperature (°C)	Irrigation Coverage (%)	Population Density (per sq. km)
Baragarh	21.33	83.62	Flat plains	Alluvial	1200-1400	25-35	70%	262
Deogarh	21.53	84.72	Undulating terrain	Lateritic	1400-1600	22-32	30%	91
Ganjam	19.37	84.78	Coastal plains	Loamy	1300-1500	26-36	50%	429
Jharsuguda	21.87	83.92	Flat terrain	Fertile Alluvial	1200-1400	25-35	45%	274
Kalahandi	19.91	83.17	Hilly and valleys	Mixed (fertile)	1200-1500	23-34	55%	199
Koraput	18.82	82.73	Hilly terrain	Red and lateritic	1400-1600	20-30	25%	154
Nabarangpur	19.22	82.55	Undulating terrain	Loamy	1200-1400	23-34	20%	230
Sambalpur	21.47	83.97	Plains and hills	Mixed (fertile)	1200-1500	25-35	60%	223

Source: Odisha Statistical Abstract, 2023

2.1.2. Socio-Economic Characteristics

The region is predominantly agrarian, with small and marginal farmers comprising the majority of the population. Many districts, such as Kalahandi, Koraput, and Nabarangpur, have significant tribal populations that rely on subsistence farming. In contrast, areas like Bargarh and Sambalpur, known for their higher agricultural productivity, face challenges in effectively utilizing rice fallows during the *Rabi* season. Persistent socio-economic constraints, including poverty, limited irrigation infrastructure, and traditional crop practices, underscore the need for scientific interventions to enhance agricultural productivity. However, the presence of strong community structures, such as women-led Self-Help Groups (SHGs) and Farmer Producer Organizations (FPOs), provides a solid foundation for implementing sustainable and inclusive solutions.

District	Area (In ha)
Bargarh	16,500
Deogarh	4,600
Ganjam	6,850
Jharsuguda	5,350
Kalahandi	21,000
Koraput	7,750
Nabarangpur	17,050
Sambalpur	14,750
Total	**93,850**

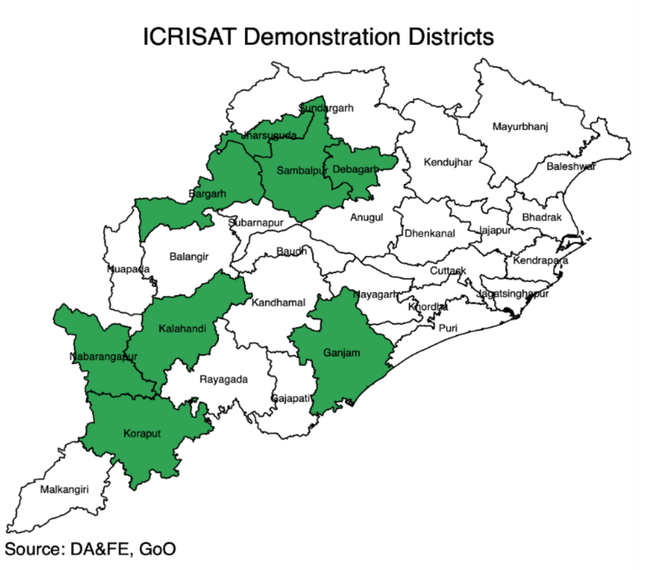
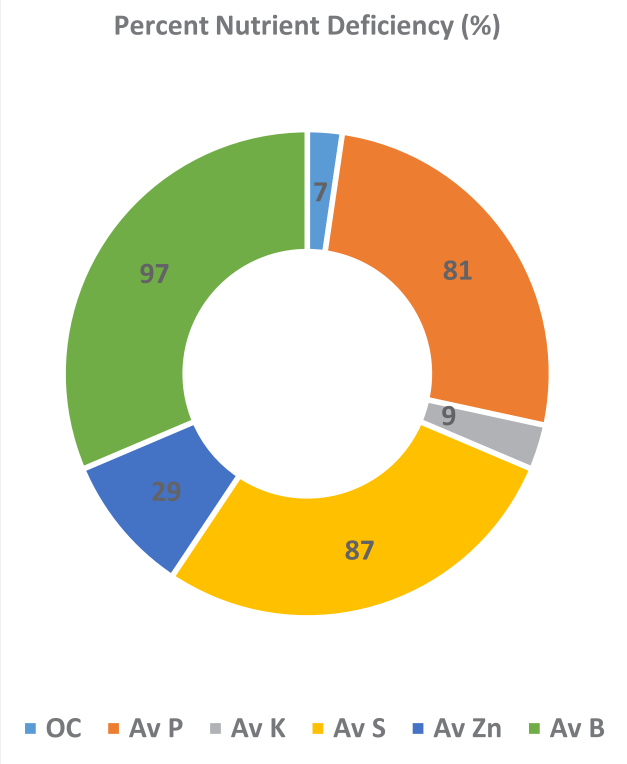


Figure 1: District-wise rice-fallow area coverage under CPRFM 2023-24
Source: DA&FE, Government of Odisha and ICRISAT

2.2 Soil Health Analysis



A comprehensive pre-sowing soil health analysis was conducted to assess nutrient availability and soil fertility status in the project areas. The findings indicate that most soil samples were acidic, with a mean pH of 5.4, suggesting the need for pH management through lime application or organic amendments. The organic carbon (OC) content in the soils was found to be adequate, reflecting good organic matter presence and potential for microbial activity. However, significant nutrient deficiencies were observed across key macro and micronutrients.

Phosphorus (P) deficiency was recorded in 81% of the soil samples, which could limit plant root development and overall productivity. Conversely, potassium (K) content was found to be optimal, indicating a lesser need for potassium fertilization in these soils. Among secondary nutrients, sulphur (S) deficiency was prominent in 87% of samples, highlighting the necessity for sulphur-enriched fertilizers to support crop metabolism. Furthermore, micronutrient deficiencies were also prevalent, with zinc (Zn) and boron (B) deficiencies observed in 29% and 97% of the samples, respectively, which could negatively impact plant growth, flowering, and grain formation.

These findings emphasize the importance of adopting balanced fertilization strategies and integrated soil fertility management (ISFM) to improve soil health and sustain agricultural productivity. Based on these recommendations the inputs were included in the management practices.

3. Project Objectives

The specific objectives of the present CPRFM initiative in Odisha are as follows;

1. Upscaling the area of pulses and oilseed in rice fallows by exploring residual soil moisture.
2. Restoring soil health by increasing the soil biomass and organic carbon of soil.
3. Enhancing the livelihood of farmers through improved income and nutrition.
4. Increasing seed security in drylands through community participation and capacity building.

4. Study Objectives

The primary objective of this study was to assess and document the initial impact of the CPRFM 2023-24 on farmers in the targeted districts. The project made significant efforts to reach 152,601 farmers and covered 93,850 hectares of rice-fallow land across eight districts in Odisha. To promote sustainable agricultural intensification, the project strategically introduced and encouraged the adoption of short-duration pulses, including chickpea, green gram, black gram, lentil, and field pea, along with oilseed crops such as mustard. Understanding the performance of these crops across diverse agro-ecologies and soil types is crucial, as their productivity may vary depending on farm infrastructure, irrigation access, and agro-climatic conditions. The project also facilitated access to seeds, crop demonstrations, and capacity-building activities, which were intended to support farmers in the adoption of these crops. However, the extent to which these interventions influenced agricultural outcomes required further examination.

To comprehensively evaluate these outcomes, a primary household survey was designed to cover both project beneficiaries, who were direct participants, and control-1 farmers, who were non-beneficiaries residing in the same project villages. This approach aimed to clearly distinguish the benefits experienced by project participants compared to non-participating farmers. Additionally, a control-2 group, consisting of farmers from non-project villages with similar agro-ecological conditions, was included to establish a baseline for evaluating the project's overall impact.

Feedback from surveyed farmers provided valuable insights into key challenges encountered during crop cultivation and marketing, as well as the utilization patterns of additional production and its contribution to food and nutritional security. Given these complexities, the study adopted a systematic approach to gather comprehensive farmer feedback, not only to assess the project's initial impact but also to identify critical constraints faced by farming communities. These findings are essential for designing evidence-based strategies that optimize the effectiveness of future project implementations and ensure long-term sustainability.

5. Study Sampling Framework

The study employed a robust sampling strategy to address the proposed study objectives and to analyse the various drivers and challenges associated with the expansion of *Rabi* cropped areas in the project districts. To gain a deeper understanding of key issues, a large sample study was designed, comprising a mix of project beneficiaries and non-beneficiaries from the project villages. Beneficiary farmers are those who directly participated in the project, gaining access to improved seeds, other inputs, and necessary capacity-building activities.

The non-beneficiary farmers were categorized into two groups:

- **Control-1:** Farmers residing in the project-targeted villages but not benefiting from the project interventions.
- **Control-2:** Farmers from non-project villages, with no direct or indirect exposure to project interventions or technologies. These villages were selected based on their similarity to project villages in terms of agro-ecological and socio-economic characteristics.

This categorization was specifically designed to establish an appropriate counterfactual for future impact assessment activities, enabling a robust evaluation of the project's outcomes.

Table 2: Sampling Framework and Strategy for the Study

Study district	Beneficiaries	% Beneficiaries HH	Control-1	% Control-1 HH	Control 2	% Control-2 HH	Total	% total
Bargarh	200	59.0	60	17.7	79	23.3	339	15.6
Deogarh	80	57.1	20	14.3	40	28.6	140	6.4
Ganjam	85	60.7	14	10.0	41	29.3	140	6.4
Jharsuguda	60	50.0	20	16.7	40	33.3	120	5.5
Kalahandi	240	63.2	60	15.8	80	21.1	380	17.5
Koraput	163	44.5	122	33.3	81	22.1	366	16.9
Nabarangpur	243	63.6	59	15.5	80	20.9	382	17.6
Sambalpur	184	60.3	61	20.0	60	19.7	305	14.0
Total	**1255**	**57.8**	**416**	**19.2**	**501**	**23.1**	**2172**	**100.0**

The study initially aimed to allocate approximately 50% of the sample to the beneficiary category, while 25% was designated for Control-1 and the remaining 25% for Control-2 (Table 2). However, due to various field constraints, the final sample distribution deviated slightly from the original plan. Ultimately, about 58% of the total sample belonged to the beneficiary category, followed by 23% in Control-2 and 19% in Control-1. The proportions of different farmer categories varied across districts due to field-based limitations, including farmer availability during the survey and logistical challenges.

6. Study Methodology

The study developed a comprehensive survey instrument for the primary household survey, covering both quantitative and qualitative aspects. The survey instrument was pre-tested, and necessary modifications were made to ensure the collection of relevant and accurate information from the sample farmers. The field team dedicated nearly three months to conducting the survey, collecting data from approximately 2,172 sample households. Additionally, extensive time was allocated to data cleaning, validation, and outlier removal to enhance data accuracy and reliability.

The analytical approach included descriptive tabular analyses, performed using STATA (v16.0), to examine trends in socio-economic characteristics, landholdings, cropping patterns, project crop performance, crop productivity levels, output utilization, and household income dynamics. The analysis also sought to document the initial impacts observed among project beneficiaries in comparison to Control-1 and Control-2 farmers. Furthermore, an econometric approach is being applied to isolate and measure project impacts among the three farmer categories, ensuring a rigorous evaluation of the intervention's effectiveness.

7. Variables of Interest

The study focuses on a range of key variables to assess the impact of the CPRFM 2023-24 on targeted farmers. These variables were carefully selected to capture both quantitative and qualitative dimensions of the intervention's outcomes. The socio-economic characteristics of households, including household size, education level, landholdings, and access to credit, provide insights into the baseline conditions of the surveyed farmers. Cropping patterns and land use data help in understanding shifts in agricultural practices, particularly the adoption of short-duration pulses and oilseeds in rice-fallow lands.

In addition, the study evaluates crop productivity levels, comparing the performance of project-introduced crops with traditional farming practices. Another crucial aspect examined is the suitability of different land types for the introduced crops, assessing where these crops performed optimally based on factors such as soil characteristics, residual moisture availability, and farm infrastructure. Understanding which land types best support *Rabi* intensification is critical for scaling up interventions effectively. Household income sources and patterns are critical variables for measuring the economic impact of the project, particularly changes in agricultural income, labor employment, and market participation. The study also explores food and nutritional security indicators, such as dietary diversity and household food consumption patterns, to assess potential improvements in well-being.

To establish a rigorous comparison, these variables are examined across three farmer categories - project beneficiaries, Control-1 (non-beneficiaries from project villages), and Control-2 (farmers from non-project villages with similar agro-ecological conditions). This structured analysis allows for a comprehensive evaluation of the project's reach and effectiveness while isolating key factors influencing its impact. Additionally, econometric methods are applied to control for external variables and better quantify the differences observed across farmer categories. This multi-dimensional approach ensures a holistic understanding of the project's outcomes, providing evidence-based insights for optimizing future interventions and policymaking in rice-fallow management.

8. Study Findings

The CPRFM 2023-24 was implemented to explore the potential of expanding *Rabi* cultivation in rice-fallow lands across Odisha, with a focus on promoting short-duration pulses and oilseeds. Given the challenges farmers face with utilizing these lands - such as limited irrigation, low soil fertility, and restricted access to quality seeds the project aimed to enhance crop productivity, household incomes, and food security through targeted interventions.

This study was undertaken to assess the early outcomes of the CPRFM initiative by comparing project beneficiaries with two control groups: Control-1 (non-beneficiaries in project villages) and Control-2 (farmers from non-project villages with similar agro-ecological conditions). The objective was to document the extent of *Rabi* crop expansion, analyse productivity differences, evaluate household-level economic benefits, and assess changes in food and nutritional security.

The findings presented in this report provide a comprehensive analysis of various factors influencing *Rabi* intensification, including landholding patterns, land type suitability for introduced crops, cropping trends, productivity levels, income generation, and market participation. Special attention is given to the performance of project-introduced crops, the economic viability of *Rabi* farming, and the broader implications for smallholder farmers in Odisha. Additionally, the study examines barriers to adoption and identifies key drivers of success in *Rabi* crop expansion.

By systematically comparing the experiences of different farmer groups, this report aims to offer evidence-based insights into the effectiveness of the CPRFM interventions.

8.1 Socio-Economic Characteristics of the Sample

The study examined the socio-economic profiles of surveyed households to understand the diversity within the sample. Table 3 presents the distribution of household heads by gender across the three categories: project beneficiaries (participating farmers), Control-1 (non-beneficiaries from project villages), and Control-2 (farmers from non-project villages with similar agro-ecological conditions).

Table 3: Gender Distribution of Household Heads (% of Households)

Gender	Beneficiaries	Control-1	Control 2	Total
Female	29.1	29.6	29.7	29.3
Male	70.9	70.4	70.3	70.7

Out of the total surveyed households, 29.3% were female-headed, while 70.7% were male-headed. This pattern remained consistent across the three groups, with female-headed households comprising 29.1% of beneficiaries, 29.6% of Control-1 farmers, and 29.7% of Control-2 farmers. Female-headed households play a critical role in agricultural decision-making, particularly in regions where male migration is prevalent. They significantly contribute to agricultural production, household dietary management, and overall food security. These findings highlight the importance of gender-sensitive interventions in agricultural programs to address the unique challenges faced by female-headed households. Targeted policies that enhance their access to resources, training, and markets can significantly improve productivity, income, and nutritional security.

Table 4: Age Distribution of Household Heads (In years)

Category	N	Mean	SD	Min	Max
Beneficiary	1255	48.0	12.3	20	84
Control-1	416	46.3	12.9	22	78
Control 2	501	45.8	12.0	22	80
Total	2172	47.2	12.4	20	84

The age distribution of household heads is summarized in Table 4, capturing variations across different farmer categories. The average age of household heads in the total sample was 47 years, ranging from 20 to 84 years. Beneficiary households had a slightly higher mean age (48 years) compared to Control-1 (46.3 years) and Control-2 (45.8 years). The broad age distribution reflects diversity in farmer experience and decision-making across the sample.

Table 5: Average Household Size (Number of members per Household)

Category	N	Mean	SD	Min	Max
Beneficiary	1255	5.0	2.2	1	17
Control-1	416	4.7	1.8	1	12
Control 2	501	5.1	2.1	1	19
Total	2172	5.0	2.1	1	19

Household size is a critical socio-economic factor influencing labor availability, consumption patterns, and income levels. Table 5 presents the average household size across different farmer categories. The mean household size in the study sample was 5 members per household, ranging from 1 to 19 members. The Control-2 group had a slightly larger household size (5.1), while Control-1 had a slightly lower average (4.7). These findings indicate that household size variations may influence labor availability, resource allocation, and agricultural decision-making.

Table 6: Social Categorization of Study Sample (% of Households)

Social category	Beneficiaries	Control-1	Control 2	Total
Scheduled Caste (SC)	10.7	16.4	9.8	11.6
Scheduled Tribe (ST)	33.3	39.7	41.3	36.4
Other Backward Castes (OBC)	52.4	40.9	40.3	47.4
General (OC)	3.6	3.1	8.6	4.7
Total	100	100	100	100

Table 6 presents the distribution of surveyed households by social category. The majority of the surveyed households belonged to the Other Backward Castes (OBC) category (47.4%), followed by Scheduled Tribe (ST) (36.4%), Scheduled Caste (SC) (11.6%), and a smaller proportion from the General Category (4.7%). This distribution suggests that a significant portion of the sample belongs to historically marginalized communities, reinforcing the importance of inclusive agricultural interventions that cater to socially disadvantaged groups.

Table 7: Educational Status of Household Heads (% of Households)

Education	Beneficiaries	Control-1	Control 2	Total
Illiterate	27.7	35.8	25.8	28.8
Below Primary	15.3	11.5	12.6	14.0
Primary	15.8	17.3	19.0	16.8
Upper Primary	12.4	13.0	13.2	12.7
Secondary	17.1	13.5	16.2	16.2
Higher Secondary	7.7	6.3	9.8	7.9
Graduation	3.4	2.2	2.8	3.0
Post-Graduation	0.3	0.5	0.2	0.3
Diploma/certification	0.4	0.0	0.6	0.4
Total	100	100	100	100

Education levels of household heads are key indicators of human capital, influencing agricultural knowledge, decision-making, and adoption of improved technologies. More than one-quarter (28.8%) of the sample was illiterate, with primary education (16.8%) and secondary education (16.2%) being the most common levels attained. Higher education levels were low, with only 3% of household heads having completed graduation. This low literacy rate may impact farmers' ability to access and apply improved agricultural practices, highlighting the need for farmer training and extension programs.

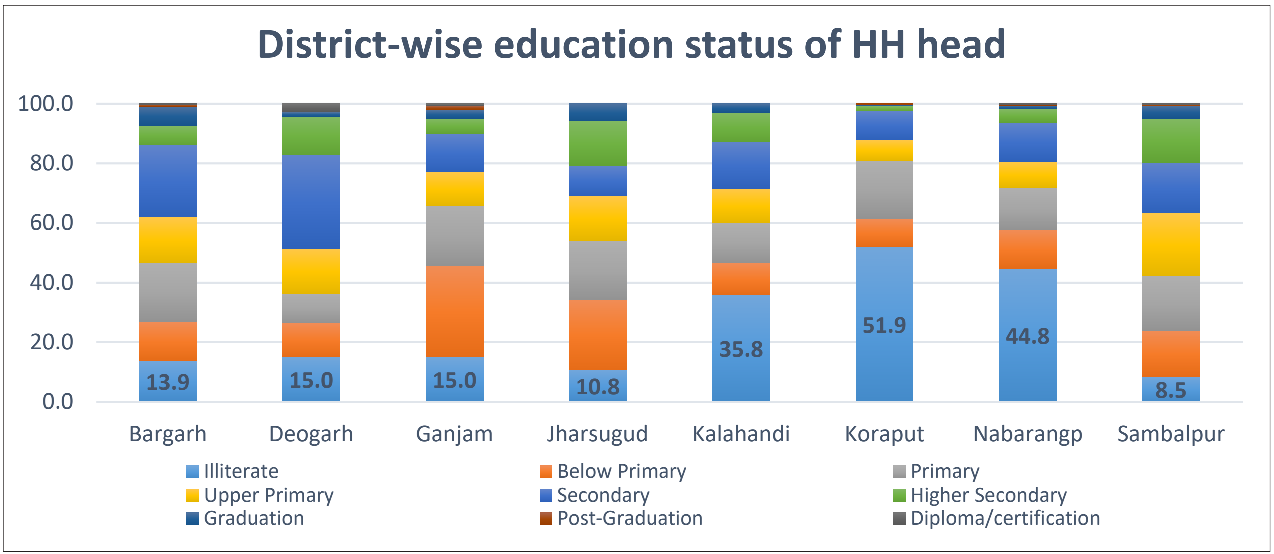


Figure 2: Educational status of household head by district

Figure 2 presents the educational status of household heads across the study districts. The highest illiteracy rate was observed in Koraput (51.9%), followed by Nabarangpur (44.8%) and Kalahandi (35.8%), indicating significant educational challenges in these regions. In contrast, Sambalpur district recorded the lowest illiteracy rate (8.5%), suggesting relatively better educational attainment among farmers in that area. These findings highlight substantial district-wise disparities in educational levels, which may have a direct influence on farmers' decision-making processes, particularly regarding the adoption of improved *Rabi* technologies and agricultural practices. Higher illiteracy rates could limit access to agricultural extension services, hinder awareness of modern farming techniques, and affect the uptake of government support programs. Addressing these gaps through targeted literacy programs, farmer training initiatives, and digital agricultural extension services could significantly enhance technology adoption and productivity outcomes across districts.

Table 8: Educational Status of Women-Headed Households (% of Households)

Education	Beneficiaries	Control-1	Control 2	Total
Illiterate	**14.3**	**22.8**	**14.4**	**16.0**
Below Primary	6.3	7.7	8.2	7.0
Primary	11.2	16.4	13.0	12.6
Upper Primary	15.1	16.1	16.6	15.6
Secondary	**24.5**	**20.7**	**23.0**	**23.4**
Higher Secondary	**15.9**	**10.6**	**15.4**	**14.8**
Graduation	11.0	4.6	8.8	9.3
Post-Graduation	1.7	1.2	0.8	1.4
Total	100	100	100	100

The educational status of women-headed households across the sample categories is presented in Table 8. The illiteracy rate among women-headed households stood at 16%, which is significantly lower than the total sample illiteracy rate of 29%. This suggests that women household heads in the surveyed areas had relatively better access to education compared to the general population. Among literate women-headed households, the highest proportion had attained secondary-level education (23.4%), followed closely by upper primary (15.6%) and higher secondary (14.8%) education. Notably, 10.7% of women-headed households had attained education beyond secondary level, including graduation (9.3%) and post-graduation (1.4%). These figures indicate that a considerable proportion of women household heads have achieved higher education levels, potentially enabling them to make more informed agricultural, financial, and household decisions.

The trends observed in Table 8 also highlight variations across farmer categories. The Control-1 group (non-beneficiaries in project villages) exhibited the highest illiteracy rate (22.8%), whereas beneficiary and Control-2 households had relatively lower illiteracy rates (14.3% and 14.4%, respectively). The findings underscore the need for continued educational support and empowerment programs for women-headed households, as education plays a crucial role in enhancing agricultural productivity, improving household income, and strengthening decision-making capabilities.

Table 9: Primary Occupations of Sample Households (% of Households)

Primary Occupation	Beneficiaries	Control-1	Control 2	Total
Agriculture	**84.8**	**79.8**	**83.8**	**83.6**
Livestock/Animal husbandry	0.5	0.2	0.4	0.4
Fisheries	0.1	0.2	0.2	0.1
Poultry	0.0	0.0	0.2	0.1
Agricultural wage labour	0.8	1.7	1.6	1.2
Non-agricultural wage	**5.3**	**9.1**	**6.0**	**6.2**
Salaried – Regular	2.4	1.9	0.8	1.9
Salaried – Contractual	1.3	1.0	1.6	1.3
Trade and business	**3.4**	**3.9**	**4.0**	**3.6**
Retired / Pension	0.3	0.5	0.6	0.4
Self-Employed	0.4	1.0	0.6	0.6
Remittances	0.9	0.7	0.2	0.7
Total	100	100	100	100

The primary occupational status of the surveyed households is presented in Table 9. The majority (83.6%) of the total sample households reported agriculture as their primary occupation, indicating a strong dependence on farming as the main livelihood source. This trend was observed across all three farmer categories, with beneficiaries (84.8%), Control-1 farmers (79.8%), and Control-2 farmers (83.8%) primarily engaged in agriculture. Following agriculture, non-agricultural wage labor constituted the second-largest occupation, accounting for 6.2% of the total sample, with the highest proportion among Control-1 households (9.1%). This suggests that non-beneficiaries from project villages may have greater reliance on off-farm employment opportunities. Trade and business emerged as the third most common livelihood source (3.6%), reflecting a limited presence of self-employment or entrepreneurial activities in the surveyed regions.

Dependence on livestock rearing (0.4%), fisheries (0.1%), and poultry (0.1%) as primary occupations was minimal, indicating that these activities are largely supplementary rather than major income sources. Similarly, the proportion of households engaged in salaried employment (1.9% for regular jobs and 1.3% for contractual jobs) remained low, suggesting limited access to formal employment opportunities. The data also indicates a negligible presence of remittances (0.7%) as a household income source, implying low levels of migration-driven earnings within the surveyed sample.

The similarity in occupational trends across all three farmer categories highlights the dominant role of agriculture in rural livelihoods. The findings underscore the need for diversification opportunities, including improved access to off-farm employment, promotion of livestock-based enterprises, and support for rural entrepreneurship to enhance income security and resilience among farming households.

Table 10: Household Asset Ownership Profile (% of Households Possessing Specific Assets)

Type of Assets	Beneficiary	Control-1	Control 2	Total
Bicycle	87.3	86.8	85.2	86.7
Carts	1.6	1.9	2.6	1.9
Chaff Cutter	4.9	13.2	5.6	6.6
Computer	1.0	0.5	0.8	0.9
Tablets	1.0	0.5	0.4	0.7
Laptop	1.5	1.0	1.2	1.3
Electric Fan	87.0	83.7	88.6	86.7
Cooler	22.5	18.5	21.8	21.6
Four-Wheeler	1.4	1.2	1.6	1.4
Tractor	2.5	0.2	2.2	2.0
Drip Irrigation	2.2	1.9	1.6	2.0
Sprinkler	0.8	0.5	1.6	0.9
Tubewell / Borewell	7.5	4.6	6.8	6.8
Pick up/Trolley/Zarang	0.3	0.2	0.0	0.2
Plough sets	24.1	19.5	18.0	21.8
Power Tiller	6.1	1.7	3.4	4.6
Radio	0.3	0.7	0.6	0.5
Refrigerator	12.1	7.2	15.4	11.9
Sprayer	26.8	16.3	16.2	22.3
Television	42.6	35.3	48.9	42.7
Two-Wheelers	52.8	42.1	51.9	50.6
Wheel barrows	0.2	0.0	0.4	0.2
Submersible	1.2	0.7	1.8	1.2
Paddy Thresher	0.2	0.0	0.6	0.3
Diesel engine	4.0	1.0	1.8	2.9

Table 10 presents the asset ownership patterns among sample households. This analysis provides valuable insights into the level of mechanization, mobility, and household resources, highlighting key disparities across different categories.

Farm Mechanization

Mechanization levels remain low across the surveyed households. Only 2% of total households owned tractors, while 7% had access to tube wells or bore wells, indicating a continued reliance on traditional plowing methods. Additionally, approximately 22% of households owned plough sets, whereas only 5% possessed power tillers, reflecting limited adoption of mechanized farming equipment. These findings suggest a high dependency on manual labor and traditional agricultural practices, which may impact overall productivity and efficiency.

Mobility and Transportation

Two-wheelers were the most common means of transportation, with 50.6% of households owning one. This indicates a reliance on motorbikes for agricultural activities, market access, and daily mobility needs. Ownership of four-wheelers remained extremely low (1.4%), suggesting limited access to more advanced transportation options.

Household Appliances and Living Standards

Ownership of televisions (42.7%) suggests that a significant proportion of households rely on television as a primary source of entertainment and sometime for agricultural information. However, refrigerators were owned by only 11.9% of households, indicating limited access to modern storage facilities, which could affect food preservation and consumption patterns.

Agricultural Equipment

The adoption of modern agricultural tools remains limited. Sprayers were owned by 22.3% of households, while paddy threshers were found in only 0.3% of the sample, indicating that most farmers rely on manual threshing methods. Ownership of advanced irrigation technologies was also low, with drip irrigation systems (2%) and sprinklers (0.9%) being minimally adopted. This suggests a strong need for improved irrigation access and modern farming interventions.

Technology and Communication

Digital technology adoption within farming households was limited in terms of advanced devices, with only 1.3% of households owning laptops, 0.9% owning computers, and 0.7% possessing tablets. However, smartphone ownership was widespread, suggesting that while access to digital tools exists, its utilization for agricultural purposes, digital banking, and modern extension services may still be limited or underutilized.

Table 11: Livestock Ownership Patterns among Sample Households (% of Households)

Type of livestock	Beneficiary	Control-1	Control 2	Total
Buffalo	4.8	5.8	3.6	4.7
Cross-bred cattle	6.4	3.4	7.0	5.9
Indigenous	**17.2**	**13.7**	**16.4**	**16.3**
Heifers/Calves	**17.1**	**12.7**	**15.0**	**15.8**
Bullocks	**17.3**	**11.8**	**13.0**	**15.2**
Goats	13.6	11.5	11.2	12.7
Sheep	4.7	5.0	6.2	5.1
Chicken	**25.3**	**30.8**	**24.4**	**26.2**
Pigs	0.1	0.0	0.2	0.1
Ducks	1.5	1.2	1.8	1.5
Camels	0.0	0.0	0.0	0.0
Horses	0.0	0.0	0.0	0.0
Others	0.4	0.7	1.0	0.6

Table 11 presents the distribution of livestock ownership among surveyed households. The analysis indicates a relatively low level of livestock possession, with approximately 15% of households owning livestock across all categories. The ownership pattern is largely consistent across beneficiaries, Control-1, and Control-2 households, showing minimal variation.

Cattle Ownership

Indigenous cattle, heifers/calves, and bullocks were the most commonly owned livestock, with 16.3%, 15.8%, and 15.2% of households owning them, respectively. In contrast, ownership of buffaloes (4.7%) and cross-bred cattle (5.9%) was significantly lower, indicating limited investment in high-value livestock. The predominance of indigenous breeds suggests a reliance on traditional cattle-rearing practices, which may be due to limited access to improved breeds, veterinary services, or financial constraints.

Small Ruminants and Poultry

Poultry farming was the most widely adopted livestock activity, with 26.2% of households owning chickens. Additionally, goat rearing was notable, with 12.7% of households reporting ownership. Small ruminants and poultry play a crucial role in household nutrition and provide supplementary income for farming families, particularly in resource-constrained settings.

Minimal Ownership in Other Livestock Categories

Ownership of other livestock such as sheep (5.1%), pigs (0.1%), and ducks (1.5%) was minimal, indicating that these livestock types are not commonly reared in the surveyed regions. Camels and horses were entirely absent, reinforcing the fact that large-scale livestock farming is not a dominant livelihood strategy in these areas.

The pattern of livestock ownership remained consistent across beneficiaries, Control-1, and Control-2 households, suggesting that constraints such as limited access to improved breeds, financial resources, and market opportunities are uniform across farmer categories. The findings highlight the dependence of farming households on indigenous cattle and small ruminants, with limited diversification into high-value or commercial livestock. This suggests potential areas for intervention to enhance livestock-based livelihoods, such as promoting improved breeds, providing better veterinary services, and supporting access to livestock markets.

8.2 Landholding Details

The landholding details of sample households across different categories are summarized in Table 12. The total operational landholding for the overall sample stands at 2.78 acres per household, which includes 2.44 acres of owned land, 0.41 acres of leased-in land, and 0.06 acres of leased-out land. Among the three sample categories, beneficiary households had the highest land ownership (2.60 acres) and operational landholding (2.98 acres), followed by Control-2 households (2.79 acres) and Control-1 households (2.18 acres). These trends align with the general landholding patterns observed across the state.

Table 12: Landholding Size by Category (Acres per Household)

	Landholding details (in acres per HH)			
Type of land	**Beneficiary**	**Control-1**	**Control-2**	**Total**
Owned land	2.60	1.95	2.44	2.44
Leased-in land	0.43	0.30	0.43	0.41
Leased-out land	0.06	0.07	0.08	0.06
Total operational land	2.98	2.18	2.79	2.78

A land market exists in the study districts, where leased-in land (0.41 acres per household) is significantly higher than leased-out land (0.06 acres per household), suggesting that many farmers engage in land leasing to expand their cultivable area.

Table 13: Mean Operational Landholding by District (Acres per Household)

District	Beneficiary	Control-1	Control 2	Total
Bargarh	**4.13**	**2.19**	**2.97**	**3.51**
Deogarh	**1.11**	**1.10**	**1.46**	**1.21**
Ganjam	2.41	1.33	3.25	2.55
Jharsuguda	3.60	3.40	2.86	3.32
Kalahandi	3.01	3.22	3.46	3.14
Koraput	2.41	1.75	2.73	2.26
Nabarangpur	3.07	2.44	2.71	2.90
Sambalpur	2.93	1.91	2.39	2.62
Total	2.98	2.18	2.79	2.78

Table 13 presents the district-wise mean operational landholding per household. Among the study districts, Bargarh recorded the highest mean operational landholding (3.51 acres per household), while Deogarh had the lowest (1.21 acres per household). Variations across districts are largely attributed to differences in land ownership patterns, access to leased-in land, and land-use practices. The variation in operational landholding across districts and categories suggests that land access plays a crucial role in determining the agricultural potential of different farmer groups.

Table 14: Mean Irrigated Landholding per Household (Acres)

	Beneficiary		Control-1		Control 2		Total	
District	Irrigated area	% in OLH	Irrigated area	% in OLH	Irrigated area	% OLH	Irrigated area	% OLH
Bargarh	1.90	46	1.08	49.4	0.73	24.5	1.48	42.2
Deogarh	0.40	36.1	0.74	66.7	0.65	44.4	0.52	43.0
Ganjam	0.23	9.5	0.04	3.2	0.68	21	0.34	13.4
Jharsuguda	1.05	29.2	1.38	40.4	0.15	5.2	0.81	24.2
Kalahandi	0.74	24.8	0.76	23.6	1.25	35.9	0.85	27.2
Koraput	0.39	16.3	0.30	17	0.29	10.5	0.34	14.9
Nabarangpur	0.42	13.5	0.21	8.5	0.30	11.1	0.36	12.4
Sambalpur	1.02	34.7	0.50	26.3	1.39	58.2	0.99	37.7
Total	**0.82**	**27.5**	**0.56**	**25.6**	**0.69**	**24.9**	**0.74**	**26.6**

OLH: Operational Land Holding

The mean irrigated landholding per household and its corresponding share in total operational landholding are summarized in Table 14. Overall, only 26.6% (0.74 acres) of the total operational landholding (2.78 acres) had access to irrigation facilities across the study sample. This trend remained consistent across the three farmer categories, with beneficiary households having slightly better irrigation access compared to the other two groups.

Among the study districts, Bargarh, Deogarh, and Sambalpur had a relatively higher share of irrigated land than the overall sample average. In contrast, Ganjam, Koraput, and Nabarangpur had lower irrigation coverage, indicating greater reliance on rainfed agriculture. These variations highlight the need for targeted irrigation interventions in regions with limited water access, which could significantly enhance *Rabi* cropping potential and agricultural productivity.

Table 15: *Kharif* Cropped Area per Household (Acres per Household)

District	Beneficiary		Control-1		Control 2		Total	
	Cropped area in *Kharif*	% OLH	Cropped area in *Kharif*	% OLH	Cropped area in *Kharif*	% OLH	Cropped area in *Kharif*	% OLH
Bargarh	3.97	96.2	2.14	97.6	2.86	96.1	3.39	96.3
Deogarh	1.11	99.8	1.10	100.0	1.46	100.0	1.21	99.9
Ganjam	2.24	92.9	1.09	82.0	3.25	100.0	2.43	95.1
Jharsuguda	3.60	100.0	3.40	100.0	2.63	91.7	3.27	98.5
Kalahandi	2.88	96.0	3.22	100.0	3.46	100.0	3.14	100.0
Koraput	2.33	96.8	1.69	97.0	2.37	86.9	2.13	94.2
Nabarangpur	2.97	96.8	2.43	99.8	2.54	93.9	2.80	96.6
Sambalpur	2.86	97.8	1.87	98.0	2.38	99.5	2.57	98.1
Total	**2.88**	**96.7**	**2.14**	**98.3**	**2.67**	**95.6**	**2.70**	**97.2**

OLH: Operational Land Holding

The mean *Kharif* cropped area per household across different sample categories and districts is summarized in Table 15. On average, 97% of total operational landholdings (2.70 acres) were cultivated during the *Kharif* season. This percentage was slightly higher among Control-1 households (98%), followed by beneficiary farmers (97%) and Control-2 households (96%).

Among the study districts, Kalahandi recorded the highest *Kharif* land utilization (100%), followed by Deogarh (99.9%) and Jharsuguda (98.5%). In contrast, Koraput had the lowest operational land utilization for *Kharif* cropping, at 94.2%. Despite these variations, all study districts exhibited high land utilization for *Kharif* crops, with more than 94% of total operational landholdings cultivated during the season.

These findings indicate that *Kharif* season cropping is near saturation across all study districts, emphasizing the importance of improving productivity rather than expanding cultivation area. Future interventions should focus on enhancing yield potential, optimizing input use, and adopting climate-resilient cropping practices to maximize agricultural output.

Table 16: *Rabi* Cropped Area per Household (Acres per Household)

District	Beneficiary		Control-1		Control 2		Total	
	Cropped area in *Rabi*	% OLH	Cropped area in *Rabi*	% OLH	Cropped area in *Rabi*	% OLH	Cropped area in *Rabi*	% OLH
Bargarh	2.07	50.1	1.12	51.4	0.76	25.4	1.59	45.4
Deogarh	0.63	56.5	0.97	87.7	0.43	29.6	0.62	51.3
Ganjam	1.30	53.9	0.44	33.2	1.35	41.5	1.23	48.2
Jharsuguda	1.33	37.0	1.14	33.4	0.20	7.0	0.92	27.8
Kalahandi	1.31	43.6	1.52	47.0	1.27	36.7	1.33	42.5
Koraput	1.26	52.3	0.38	21.8	0.19	7.1	0.73	32.4
Nabarangpur	1.05	34.1	0.17	6.9	0.11	3.9	0.71	24.6
Sambalpur	1.59	54.2	0.54	28.2	1.33	55.5	1.33	50.6
Total	**1.37**	**46.1**	**0.71**	**32.6**	**0.69**	**24.7**	**1.09**	**39.1**

OLH: Operational Land Holding

The extent of cropped area during the *Rabi* season across different study districts is summarized in Table 16. Overall, only 39.1% of the total operational landholding was utilized for crop cultivation during the post-rainy season.

Among the study districts, Deogarh recorded the highest *Rabi* land utilization (51.3%), whereas Nabarangpur had the lowest (24.6%). When analyzed by farmer category, beneficiary households had the highest operational land utilization for *Rabi* cropping (46.1%), followed by Control-1 farmers (32.6%) and Control-2 farmers (24.7%).

The higher *Rabi* land utilization among beneficiary farmers suggests that their participation in the Comprehensive Rice-Fallow Management (CRFM) Project facilitated the expansion of *Rabi* cropped areas. Control-1 farmers, though not direct beneficiaries, may benefited from knowledge transfer through interactions with participating farmers within the same village. In contrast, Control-2 farmers, who were not part of the CRFM Project, exhibited significantly lower *Rabi* cropping expansion. These findings highlight the impact of targeted interventions in increasing *Rabi* cropping intensity. Expanding access to technical knowledge, irrigation facilities, and improved inputs could further enhance *Rabi* crop adoption across all farmer categories, particularly among non-beneficiaries.

Table 17: Proportion of *Rabi* Cropped Area Left Fallow (% of Households)

District	Beneficiary	Control-1	Control-2	Total
Bargarh	49.9	48.6	74.6	54.6
Deogarh	43.5	12.3	70.4	48.7
Ganjam	46.1	66.8	58.5	51.8
Jharsuguda	63.0	66.6	93.0	72.2
Kalahandi	56.4	53.0	63.3	57.5
Koraput	47.7	78.2	92.9	67.6
Nabarangpur	65.9	93.1	96.1	75.4
Sambalpur	45.8	71.8	44.5	49.4
Total	**53.9**	**67.4**	**75.3**	**60.9**

The extent of *Rabi* cropped area left fallow, as a proportion of the total operational landholding across different farmer categories, is summarized in Table 17. Overall, 61% of the total *Rabi* cropped area in the sample remained fallow due to various constraints. This highlights a significant opportunity for expanding *Rabi* crop cultivation across the study districts in Odisha.

The potential for *Rabi* expansion varies across farmer categories. Beneficiary farmers have the lowest proportion of fallow land (54%), indicating that their participation in the Comprehensive Rice-Fallow Management (CRFM) Project has facilitated greater land utilization during the post-rainy season. However, Control-1 farmers (68%) and Control-2 farmers (75%) have significantly higher fallow land, demonstrating that non-beneficiaries face greater barriers to *Rabi* crop adoption.

These findings emphasize the need for targeted interventions to increase *Rabi* cropping intensity. Expanding access to quality seeds, improving irrigation facilities, and strengthening farmer extension services could help reduce fallow land and enhance agricultural productivity during the post-rainy season.

Table 18: Key Constraints for Keeping Land Fallow During *Rabi* – (% of Households)

Reason	Beneficiary	Control-1	Control 2	Total
No irrigation facilities	**78.2**	**70.4**	**66.4**	**73.8**
Irrigation available but its far away	**8.5**	**11.5**	**13.3**	**10.3**
Unavailability of seed and other inputs	**10.2**	**30.8**	**25.0**	**17.9**
Input available but it's expensive	**5.4**	**17.5**	**17.6**	**10.8**
Unavailability of farm machinery	2.3	2.4	1.4	2.1
Available but high cost of machinery	2.5	1.5	6.2	3.2
Unavailability of labor	1.8	2.1	2.6	2.1
Insect and pest attacks and diseases	4.5	6.8	10.2	6.4
Not profitable	1.5	0.9	3.6	1.9
Climate not suitable for second crop	6.7	10.9	8.6	8.0
Wild boar/monkey attacks	**12.9**	**12.4**	**15.5**	**13.4**

The analysis of reasons for keeping land fallow during the *Rabi* season, as summarized in Table 18, reveals that lack of irrigation facilities is the most significant constraint, affecting 73.8% of households across the study sample. This challenge was most severe among beneficiary farmers, with 78.2% citing irrigation unavailability as a barrier. Additionally, 10.3% of households reported that while irrigation facilities existed, they were located too far away to be practical, further restricting land use during *Rabi*. Another major constraint was the unavailability of seeds and agricultural inputs, affecting 17.9% of households, with this issue being particularly pronounced among Control-1 farmers (30.8%). High input costs further exacerbated the problem, with 10.8% of farmers identifying financial constraints as a limiting factor for *Rabi* cultivation.

Wild boar and monkey attacks also emerged as a significant challenge, impacting 13.4% of households, with Control-2 farmers being the most affected (15.5%). Other constraints included lack of farm machinery (2.1%), high machinery costs (3.2%), and labor shortages (2.1%), all of which restricted *Rabi* cropping. Insect and pest attacks (6.4%) and unsuitable climatic conditions for a second crop (8.0%) were additional barriers affecting land utilization during the post-rainy season. These findings indicate that constraints to *Rabi* cropping are largely uniform across all farmer categories, with no major category-specific variations.

It is important to understand the potential for further expansion of Rabi crops in the study districts of Odisha (Fig. 3). This will help in designing appropriate strategies for the future expansion of Rabi crops in different agro-ecological zones. The pattern of Rabi cropped area expansion from 2019-20 to 2023-24 was analyzed based on land type (lowland, midland, and upland).

The analysis clearly shows that the expansion of Rabi pulses and oilseeds in lowland areas is highly limited, as these soils are primarily suited for paddy cultivation or remain excessively moist throughout the season. Similarly, upland areas also exhibit minimal expansion potential due to low soil moisture availability during the post-rainy season.

However, midland areas present a significant opportunity for Rabi crop expansion. The data clearly shows that the cropped area in mindlands increased from 1,272 acres in 2019-20 to 1,890 acres in 2023-24. This trend strongly supports the argument that future CPRFM efforts should focus on medium land areas with the development of necessary irrigation facilities to enhance productivity and sustainability.

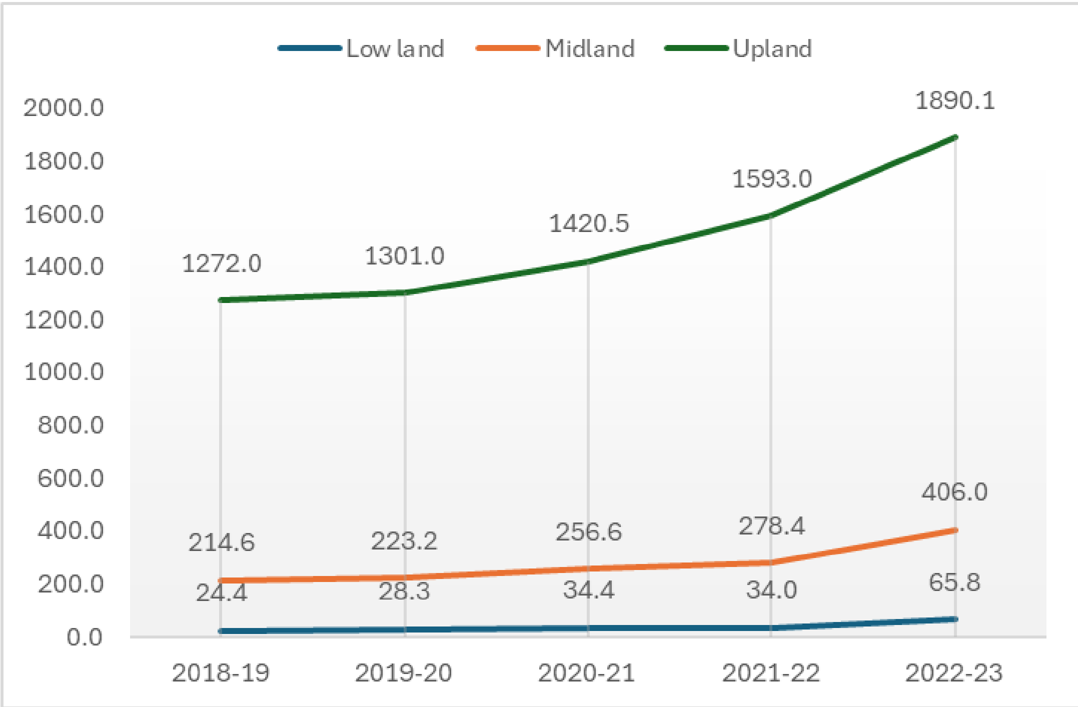


Figure 3: Rabi *cropped area (acres) expansion by land type (lowland, midland, and upland)*

Table 19: *Rabi* Cropped Area (acres) Expansion by Irrigation Source (2019-20 to 2023-24)

Irrigation source	2019-20	2020-21	2021-22	2022-23	2023-24
Rainfed/No Irrigation	567.0	639.0	721.9	855.1	1053.5
Canal / River	318.9	260.4	279.1	296.8	341.2
Tubewell/Bore well	243.9	254.1	283.9	304.1	356.5
Open well	122.9	129.8	130.5	140.0	180.3
Pond	108.2	105.4	118.9	123.5	136.9
Lift Water Irrigation	131.5	139.3	153.3	156.6	261.8
Total	1492.4	1528.0	1687.6	1876.1	2330.3

The data indicates that *Rabi* cropped area expansion has been largely driven by rainfed agriculture, with a significant increase in the area under rainfed/no irrigation conditions from 567 acres in 2019-20 to 1,053.5 acres in 2023-24 (Table 19). This trend highlights the growing reliance on residual soil moisture for *Rabi* cultivation, reinforcing the need for improved moisture conservation techniques and timely sowing strategies.

While the area under canal/river irrigation has fluctuated over the years, it saw an increase from 318.9 acres in 2019-20 to 341.2 acres in 2023-24, though its overall share in irrigation remains lower compared to previous years. Meanwhile, tubewell/borewell irrigation has steadily expanded, reaching 356.5 acres in 2023-24, indicating a gradual shift toward groundwater-based irrigation systems.

Other irrigation sources, such as open wells, ponds, and lift irrigation, have also shown moderate increases, with lift irrigation rising from 131.5 acres in 2019-20 to 261.8 acres in 2023-24. This suggests that while alternative irrigation sources are contributing to *Rabi* crop expansion, their adoption remains relatively limited in comparison to rainfed conditions.

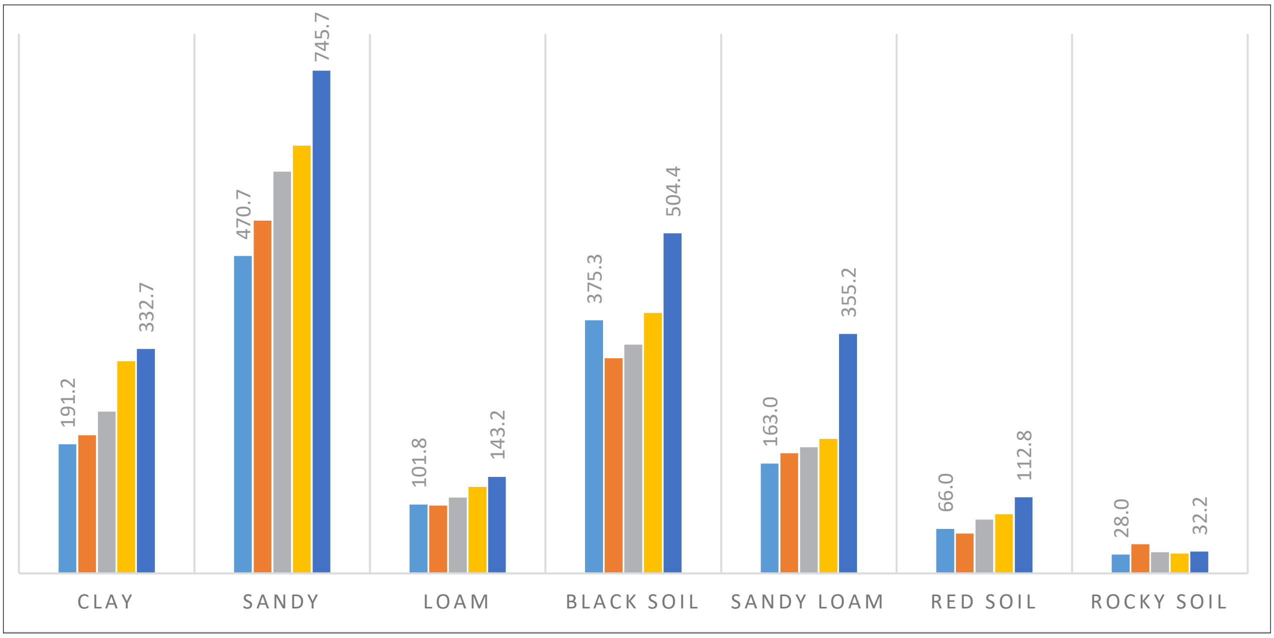


Figure 4: Rabi *cropped area expansion across different soil types (2019-20 to 2023-24)*

The expansion of *Rabi* cropped area over time has been analysed based on soil type, and the findings are summarized in Figure 4. The trends clearly indicate a higher preference for sandy, black, clay, and sandy loam soils for *Rabi* crop expansion over the last five seasons. Among these, sandy soils exhibit the highest increase in *Rabi* cropped area, reaching 745.7 acres in 2022-23, followed by black soil (504.4 acres) and sandy loam soil (352.2 acres). This indicates that these soil types are more conducive to *Rabi* crop establishment, likely due to their better moisture retention and suitability for short-duration pulses and oilseeds.

Conversely, loamy, red, and rocky soils have witnessed minimal expansion, suggesting that these soil types pose greater constraints for *Rabi* cultivation, possibly due to lower water-holding capacity, higher erosion risks, or unfavorable drainage characteristics.

8.3 Cropping Patterns

Understanding cropping patterns is essential for analyzing land use efficiency and the impact of agricultural interventions in the study area. This section examines the distribution of crops cultivated during the *Kharif* season and highlights key trends in cropping diversification among different farmer categories.

Table 20: Mean *Kharif* Cropping Pattern per Household (% of Cropped Area)

	Area under different crops (in acres)							
Type of crop	Beneficiary	% cropped area	Control-1	% cropped area	Control 2	% cropped area	Total	% cropped area
Paddy	**2.65**	**92.2**	**1.92**	**90.9**	**2.40**	**90.4**	**2.45**	**91.6**
Maize	0.03	1.1	0.02	0.9	0.03	1.1	0.03	1.1
Millet/*Ragi*	0.02	0.7	0.01	0.5	0.07	2.8	0.03	1.1
Cotton	0.05	1.6	0.03	1.6	0.04	1.5	0.04	1.6
Black gram	0.01	0.5	0.01	0.7	0.02	0.7	0.02	0.6
Green gram	0.04	1.5	0.02	0.9	0.05	2.1	0.04	1.5
Pigeonpea	0.00	0.0	0.01	0.3	0.00	0.0	0.00	0.1
Vegetables	0.03	1.1	0.02	1.1	0.02	0.8	0.03	1.0
Groundnut	0.04	1.4	0.06	3.0	0.02	0.6	0.04	1.5
Total	**2.87**	**100**	**2.10**	**100**	**2.65**	**100**	**2.68**	**100**

The analysis of the *Kharif* cropping pattern (Table 20) reveals that paddy remains the dominant crop across all sample categories, accounting for 91.6% of the total cropped area. The prominence of paddy reflects its critical role in food security and farm livelihoods. Among the surveyed groups, participating farmers allocated the highest proportion of their land (92.2%) to paddy, followed by control-1 households (90.9%) and control-2 households (90.4%).

Despite the overwhelming dominance of paddy, cropping diversification remains limited. Maize, millet (*ragi*), and green gram were cultivated on less than 2% of the total cropped area per household. Notably, millet/*ragi* accounted for 2.8% of the cropped area among control-2 households but was negligible among participating and control-1 farmers. Other minor crops included cotton (1.6%), vegetables, and groundnut, with groundnut cultivation being relatively higher among control-1 households (3.0%). Pigeonpea cultivation was nearly absent, reflecting its low adoption during the *Kharif* season.

These findings highlight the predominance of paddy and the limited diversification in cropping systems, emphasizing the need for strategies to promote crop diversification and enhance the resilience of farming systems in the region.

Table 21: District-Wise Mean *Kharif* Cropping Patterns (% of Cropped Area)

District	Paddy	Maiz	*Ragi*	Cotton	Black gram	Green Gram	Pigeonpea	Vegetables	Groundnut
Bargarh	**82.4**	0.0	0.4	0.6	1.7	7.0	0.0	3.0	5.0
Deogarh	**95.0**	0.0	0.8	0.0	1.2	0.5	0.0	1.1	1.4
Ganjam	**99.6**	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.0
Jharsuguda	**91.2**	0.0	0.0	0.0	1.0	0.8	0.9	0.4	5.7
Kalahandi	**87.4**	0.9	1.0	8.0	0.3	0.2	0.0	2.0	0.3
Koraput	**91.0**	1.5	5.1	0.0	0.3	0.0	0.0	2.0	0.0
Nabarangpur	**96.2**	3.3	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Sambalpur	**96.9**	0.3	0.6	0.0	0.1	0.5	0.0	1.7	0.0
Total	**91.0**	1.0	1.1	1.7	0.6	1.5	0.1	1.6	1.4

The district-wise mean *Kharif* cropping patterns are summarized in Table 21. The analysis clearly indicates that paddy is the overwhelmingly dominant crop across all study districts, occupying close to ~90% of operational landholdings. However, some district-level variations are observed. Bargarh (82.4%) and Kalahandi (87.4%) have a slightly lower share of paddy cultivation compared to other districts. This may be due to greater diversification of crops in these regions, where farmers allocate land to maize, cotton, vegetables, and pulses. For instance, Kalahandi has the highest share of cotton cultivation (8.0%), whereas Bargarh shows a relatively higher proportion of black gram (1.7%) and green gram (7.0%).

The cultivation of minor crops like maize, millet (*ragi*), and pulses remains low across most districts, with only Koraput showing a notable share of *ragi* (5.1%). Similarly, vegetable and groundnut cultivation is minimal, except in Bargarh (vegetables: 3.0%, groundnut: 5.0%) and Jharsuguda (vegetables: 0.4%, groundnut: 5.7%), indicating localized cropping preferences. These findings highlight the continued reliance on paddy as the primary *Kharif* crop, with limited crop diversification across districts

Table 22: Mean *Rabi* Cropping Pattern per Household (% of Cropped Area)

Type of crop	Beneficiary	% cropped area	Control-1	% cropped area	Control 2	% cropped area	Total	% cropped area
Paddy	**0.06**	**4.3**	**0.05**	**7.1**	**0.15**	**23.5**	**0.08**	**7.3**
Maize	0.01	0.8	0.00	0.0	0.01	0.9	0.01	0.7
Millet	0.00	0.1	0.00	0.5	0.01	1.1	0.00	0.3
Chickpea	**0.27**	**19.6**	**0.09**	**12.8**	**0.08**	**11.8**	**0.19**	**17.6**
Black gram	**0.13**	**9.8**	**0.08**	**11.6**	**0.04**	**5.9**	**0.10**	**9.5**
Lentil	0.02	1.7	0.01	1.4	0.00	0.2	0.02	1.4
Green gram	**0.69**	**50.9**	**0.35**	**49.4**	**0.27**	**42.5**	**0.53**	**49.5**
Pigeon pea	0.00	0.1	0.00	0.3	0.00	0.0	0.00	0.2
Vegetables	0.05	3.4	0.05	7.7	0.04	6.4	0.05	4.4
Groundnut	0.05	3.5	0.03	4.8	0.02	2.4	0.04	3.5
Field pea	0.00	0.1	0.00	0.0	0.00	0.6	0.00	0.2
Mustard	0.08	5.6	0.03	4.5	0.02	3.0	0.05	5.1
Sunflower	0.00	0.0	0.00	0.0	0.01	1.5	0.00	0.2
Sesame	0.00	0.1	0.00	0.0	0.00	0.2	0.00	0.1
Total	**1.36**	**100**	**0.69**	**100**	**0.65**	**100**	**1.07**	**100**

The analysis of the *Rabi* cropping pattern, as presented in Table 22, highlights a gradual diversification of crops during the post-rainy season across the study sample. Green gram emerged as the dominant crop, occupying 49.5% of the total *Rabi* cropped area, with similar adoption levels among participating farmers (50.9%), control-1 farmers (49.4%), and control-2 farmers (42.5%).

Chickpea (17.6%) was the second most cultivated *Rabi* crop, followed by black gram (9.5%). Interestingly, paddy, typically a *Kharif*-season crop, accounted for 7.3% of the *Rabi* cropped area, indicating a limited but existing trend of paddy cultivation in the post-rainy season, likely in areas with assured moisture availability. Mustard (5.1%) and groundnut (3.5%) were also grown, showing a moderate presence of oilseeds in the *Rabi* cropping system.

The cultivation of vegetables (4.4%) reflects their importance for both household nutrition and supplementary income generation. Other crops such as lentil (1.4%), maize (0.7%), and sunflower (0.2%) were grown on a smaller scale, highlighting limited diversification into high-value crops.

While farmers are increasingly adopting pulses and oilseeds, the overall pace of diversification remains slow due to persistent challenges such as limited irrigation facilities, restricted access to quality inputs, and weak market linkages. The cropping pattern indicates a promising shift towards climate-resilient and resource-efficient agriculture, but targeted interventions - such as expanding irrigation access, strengthening input supply chains, and implementing capacity-building programs - are essential to accelerate crop diversification and enhance *Rabi* agricultural productivity.

Table 23: District-Wise Mean *Rabi* Cropping Patterns (% of Cropped Area)

Crop	Bargarh	Deogarh	Ganjam	Jharsuguda	Kalahandi	Koraput	Nabarangpur	Sambalpur
Paddy	**14.2**	**0.0**	**0.0**	**9.0**	**4.0**	**6.0**	**0.0**	**19.4**
Maize	0.0	0.0	0.0	0.0	0.0	0.0	5.9	0.0
Millet	0.4	1.2	0.0	0.0	0.0	1.3	0.4	0.0
Chickpea	**2.7**	**0.0**	**0.0**	**0.1**	**21.9**	**34.8**	**66.0**	**3.0**
Black gram	**5.8**	**12.9**	**1.3**	**2.2**	**12.2**	**30.2**	**7.0**	**2.9**
Lentil	0.0	0.0	0.0	0.7	4.8	0.0	0.0	2.0
Green gram	**51.3**	**65.5**	**94.6**	**44.0**	**54.4**	**24.5**	**20.2**	**52.5**
Pigeon pea	0.0	0.0	0.3	0.9	0.2	0.4	0.0	0.0
Vegetables	7.9	6.0	2.8	9.3	0.4	2.8	0.5	6.8
Groundnut	11.8	0.1	0.0	8.5	1.5	0.0	0.0	0.1
Field pea	0.1	0.0	0.9	0.0	0.4	0.0	0.0	0.0
Mustard	**5.7**	**9.9**	**0.0**	**23.0**	**0.2**	**0.0**	**0.0**	**13.0**
Sunflower	0.0	4.4	0.0	0.0	0.0	0.0	0.0	0.3
Sesame	0.1	0.0	0.0	2.3	0.0	0.0	0.0	0.0
Total	100	100	100	100	100	100	100	100

The district-wise mean *Rabi* cropping patterns, presented in Table 23, highlight the dominance of pulses and oilseeds in the post-rainy season across the study districts. The key crops cultivated include green gram, chickpea, black gram, and mustard, with varying degrees of adoption based on agro-climatic conditions, soil type, and access to irrigation.

Green gram emerged as the most widely cultivated *Rabi* crop, covering 52.5% of the total cropped area. It had the highest share in Ganjam (94.6%), Deogarh (65.5%), and Bargarh (51.3%), reflecting its adaptability to residual soil moisture and relatively low irrigation requirements. However, in Nabarangpur (20.2%) and Koraput (24.5%), green gram adoption was lower, likely due to limited moisture availability or alternative crop preferences.

Chickpea accounted for 17.6% of the total cropped area, with notable coverage in Nabarangpur (66.0%), Koraput (34.8%), and Kalahandi (21.9%). This reflects its suitability for medium land areas and its ability to tolerate water stress. Its lower presence in Bargarh (2.7%) and Jharsuguda (0.1%) suggests preference for other pulses.

Black gram (9.5%) was concentrated in Koraput (30.2%) and Deogarh (12.9%), indicating its adaptability to these regions. However, its cultivation was relatively lower in Bargarh (5.8%) and Nabarangpur (7.0%), suggesting localized constraints in seed access or market linkages.

Mustard (13.0%) exhibited regional variations, with the highest cultivation in Jharsuguda (23.0%) and Deogarh (9.9%), indicating potential for expansion with better extension services and market incentives.

8.4 Trends in *Rabi* Cropped Area (2019-20 to 2023-24)

The trends in total *Rabi* cropped area across the study districts from 2019-20 to 2023-24 are presented in Figure 5. The data highlights a steady increase in *Rabi* cropped area, particularly among beneficiary farmers, after the inception of the CPRFM. A notable upward trend in the total *Rabi* cropped area is observed from 2020-21 onwards, with beneficiary farmers showing the most significant expansion (growing from 1041 acres in 2019-20 to 1720.3 acres in 2023-24, marking a 65% rise) compared to control-1 and control-2 farmers. This expansion is attributed to increased access to improved seeds, technical training, and capacity-building interventions under the project.

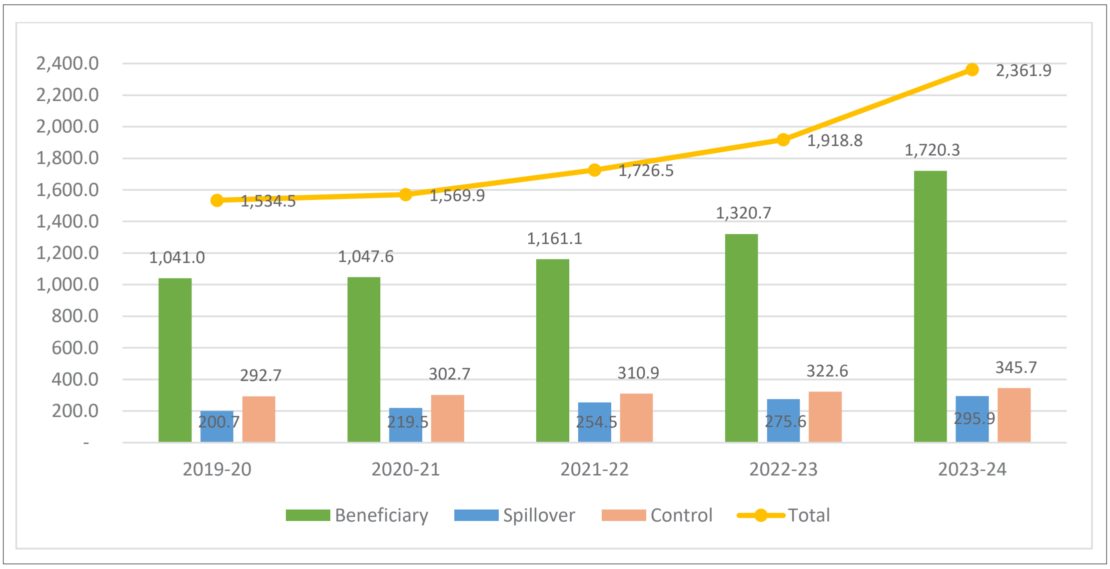


Figure 5: Trends in Rabi *cropped area expansion (2019-20 to 2023-24)*

The expansion of pulse cultivation during the *Rabi* season has shown a significant upward trend, particularly among beneficiary farmers, whose cropped area nearly doubled from 713 acres in 2019-20 to 1404.2 acres in 2023-24. Spillover farmers also exhibited steady growth, while control farmers saw only marginal increases. This highlights the impact of the CPRFM, which facilitated access to quality seeds, training, and improved agronomic practices. Despite this progress, further investment in irrigation infrastructure and input accessibility is essential to sustain and accelerate pulse adoption, particularly among non-beneficiary farmers, ensuring broader benefits in rice-fallow regions.

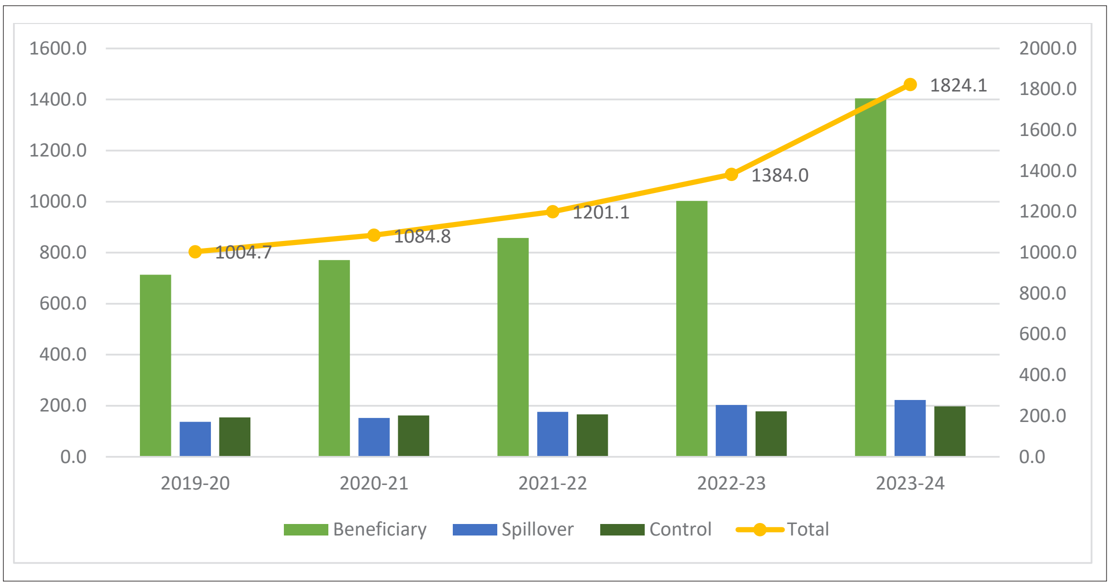


Figure 6: Expansion of pulse-cropped area in Rabi *(2019-20 to 2023-24)*

The expansion of the overall *Rabi* cropped area has shown a positive trajectory across all districts (Table 24), increasing from 1,004.7 acres in 2019-20 to 1,824.1 acres in 2023-24. Kalahandi has consistently maintained the largest share of *Rabi* cultivation, though its growth has stabilized in recent years. Bargarh and Koraput have exhibited steady increases, while Nabarangpur and Sambalpur experienced the most significant jumps in *Rabi* cropping, reflecting improved access to inputs and favorable adoption conditions. On the other hand, Jharsuguda and Deogarh have shown the least expansion, possibly due to competing high-value crops or limited irrigation facilities. These trends underscore the impact of targeted interventions and the potential for further intensification of *Rabi* cropping in districts with conducive agro-climatic conditions.

Table 24: District-Wise Trends in *Rabi* Cropped Area Expansion (2019-20 to 2023-24)

Districts	2019-20	2020-21	2021-22	2022-23	2023-24
Bargarh	224.1	237.0	257.5	279.3	323.8
Deogarh	18.7	15.2	25.4	32.7	68.1
Ganjam	142.6	150.7	155.6	150.8	166.8
Jharsuguda	39.1	49.6	54.0	57.7	52.0
Kalahandi	366.3	402.5	414.2	492.8	475.2
Koraput	99.7	107.6	129.8	153.3	239.5
Nabarangpur	34.5	41.1	69.8	83.9	254.4
Sambalpur	79.7	81.2	94.9	133.5	244.2
Total	1004.7	1084.8	1201.1	1384.0	1824.1

8.5 Performance of *Rabi* Crops

The performance of *Rabi* crops under the CPRFM demonstrated significant productivity improvements among beneficiary farmers compared to both control groups. The yield levels of black gram, green gram, lentil, chickpea, and mustard were notably higher for beneficiaries, reflecting the positive impact of project interventions.

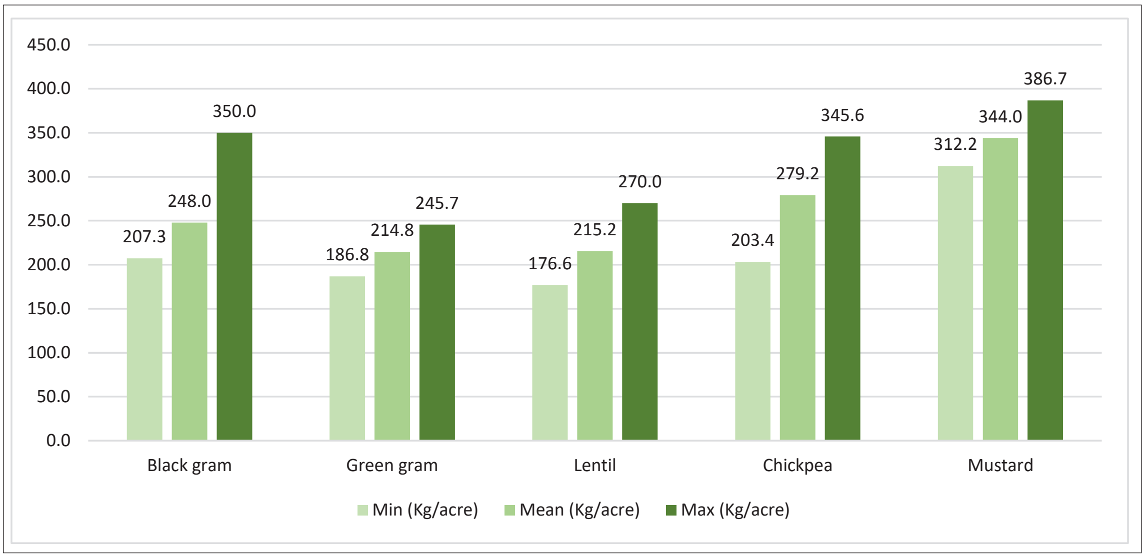


Figure 7: Productivity levels of Rabi *crops (kg per acre) for the beneficiary farmers*

Table 25: Productivity Levels of *Rabi* Crops (Kg per Acre)

Crop	Beneficiary Yield (Kg/acre)	Control-1 Yield (Kg/acre)	Control-2 Yield (Kg/acre)	Yield Increase (Beneficiary vs Control 2)	Yield Increase (Beneficiary vs Control 1)
Black gram	248.0	206.1	186.9	32.7%	10.3%
Green gram	214.8	177.9	167.7	28.1%	6.1%
Lentil	215.2	173.0	159.1	35.3%	8.8%
Chickpea	279.2	214.7	207.0	34.9%	3.7%
Mustard	344.0	294.4	258.8	32.9%	13.7%

Black gram recorded a yield of 248 kg/acre, which was 32.7% higher than control-2 and 10.3% higher than control-1. Similarly, green gram showed a 28.1% increase over control-2, while lentil exhibited the highest relative improvement, with a 35.3% increase over control-2 and 8.8% over control-1. Chickpea and mustard followed similar trends, with beneficiaries achieving 34.9% and 32.9% higher yields than control-2, respectively.

These yield enhancements can be attributed to project interventions, including the provision of quality seeds of high-yielding varieties, improved agronomic practices, timely input support, and soil conditions. Beneficiary farmers had access to quality fertilizers and biofertilizers, better pest and disease management techniques, and guidance on optimal sowing periods, which collectively contributed to improved crop establishment and productivity. The effective utilization of residual soil moisture and supplementary irrigation also played a crucial role in sustaining plant growth during the post-rainy season.

Table 26: Land Category-Wise Yield Performance (Kg per Acre).

Land Category	Beneficiary	Control 1	Control 2
Black gram			
Low land	214.4	203.4	195.3
Midland & Upland	258.3	198.7	189.4
Green gram			
Low land	190.6	183.2	183.5
Midland & Upland	224.9	164.2	158.4
Lentil			
Low land	187.9	175.3	164.3
Midland & Upland	224.3	152.3	147.3
Chickpea			
Low land	285	245	225
Midland & Upland	250	230	215
Mustard			
Low land	360.3	293	273.2
Midland & Upland	340.7	258.2	243.7

**The figures are an average of yield data taken by crop cuts and reported by the farmers*

A comparative yield analysis between short-duration and traditional long-duration varieties across land types reveals significant trends in productivity. As illustrated in Table 26, short-duration varieties demonstrated higher yields in mid and upland conditions compared to long duration varieties . For instance, short-duration varieties of black gram exhibited a yield of 258.3 kg/acre in mid and uplands as compared to 214.4 kg/acre in lowlands. Similarly, green gram recorded 224.9 kg/acre in mid and uplands as compared to 190.6 kg/acre in lowlands. Lentil also showed a similar trend recording higher yields 224.3 kg/acre in uplands as compared to 187.9 kg/acre in lowlands.

These findings reinforce the strategic advantage of introducing short-duration varieties in mid and upland rice-fallow ecosystems to maximize productivity under moisture-limited conditions. Integrating remote sensing and geospatial analysis to delineate rice-fallow typologies can enhance precision-targeted interventions, ensuring sustainable intensification and improved yield outcomes across diverse agroecological zones.

Table 27: District-Wise Cultivation Costs for Project Crops (Rupees per Acre)

District	Black gram	Greem gram	Chickpea	Mustard
Bargarh	4294.0	5897.9	4643.0	5278.5
Deogarh	5848.8	5629.7	2430.0	8451.8
Ganjam	3866.6	6797.2		
Jharsuguda	3820.0	5460.3	4100.0	7378.7
Kalahandi	4043.7	4873.8	4206.0	2620.0
Koraput	2716.4	3581.3	2561.9	
Nabarangpur	3942.4	4459.3	2594.6	
Sambalpur	3973.9	4533.1	3799.2	4547.2
Total	3672.5	5218.1	3194.4	5576.0

The district-wise costs of cultivation of project crops per acre are furnished in Table 27. Overall, the study farmers' crop investments per acre on project crops is very low and hence they realized poor productivity levels. To realize their full potential, the sample farmers need to follow and adopt the recommended package of practices. Among all, the crop investments per acre are relatively better in the case of mustard and green gram crops.

Table 28: Net Income per Acre for Project *Rabi* Crops – By Category (Rupees per Acre)

	Net profit (Total income – cost of cultivation)			
Category	Black gram	Greem gram	Chickpea	Mustard
Beneficiary	4745.3	8161.2	4513.9	7342.9
Control-1	4101.8	8074.2	2584.2	4120.1
Control 2	3194.6	6462.8	671.4	2661.7
Total	4499.0	7973.0	4002.2	6507.9

The average net income/acre earned from different project crops are summarized in Table 28. Among all crops, the mean profitability was the highest in the case of green gram followed by mustard, black gram and chickpea crops. This pattern clearly supports the expansion of green gram area in the study districts followed by black gram. The performance of mustard crops is relatively better than black gram and chickpea crops. The duration of crops and extent of moisture availability in the soil clearly determine the profitability of post-rainy season crops. Chickpea might have the longer duration (100-110 days) when compared to green gram (70 days), black gram (80-90 days) crops. Among chickpea and mustard crops, the total water requirement for chickpea is relatively higher than mustard hence the mean productivity levels are lower in case of chickpea because of moisture stress during crop maturity stage.

Table 29: District-Wise Harvest Prices of *Rabi* Crops (Rupees per Kg)

District	Mean harvest prices (Rs. per kg)				
	Black gram	Greem gram	Lentil	Chickpea	Mustard
Bargarh	93.8	93.8		68.7	80.3
Deogarh	88.0	85.1		60.0	84.5
Ganjam	85.9	81.5			
Jharsuguda	91.8	94.1		73.0	83.0
Kalahandi	88.6	85.4	61.3	67.6	83.0
Koraput	88.0	85.8		69.2	
Nabarangpur	80.8	82.7		73.6	
Sambalpur	89.1	85.6	70.0	77.8	78.8
Average	88.4	87.3	64.7	70.9	80.5

The district-wise mean harvest prices realized by sample farmers is summarized in Table 29. There are no significant differences in the mean prices realized by sample farmers across districts for project-targeted crops. These minor variations are attributed to the differences in the quality of produce as well as the value chain actor to whom they are marketing the harvest. Relatively, better prices are realized for both green gram and black gram when compared with lentil, chickpea and mustard crops. This might be the reason that many sample farmers are driving towards cultivating these crops compared to other crops.

8.6 Extent of Total Household Income

Understanding the sources of household income is essential for assessing the economic conditions of farmers in the study area and identifying potential areas for intervention (Table 30). The estimated mean annual household income for the total sample was ₹ 105,399, with agriculture contributing 67% of the total income, followed by non-farm wages (14%) and salary/contractual wages (9%). These figures indicate the significant role of agriculture in overall household income composition.

Within agriculture, *Kharif* farming contributed 52% of total household income, while *Rabi* farming accounted for 11%, suggesting its role in supplementary income generation. The distribution of farming income varied among farmer categories, with beneficiary households deriving 69% of their income from farming, compared to 65% for control-2 households and 60% for control-1 households. The share of *Rabi* farm income was also higher among beneficiary farmers (12%) compared to the other two groups.

Households that participated in the CPRFM had relatively higher income from *Rabi* farming, which may reflect differences in technology adoption, input availability, or capacity-building initiatives. Further analysis is required to determine the specific factors influencing these income variations across farmer groups.

Table 30: Sources of Annual Household Income (Rupees per Household per Year)

Source of Income	Beneficiary	Spillover	Control	Overall
Farming	76072.8	56462.9	67610.9	70365.1
Rabi farming	13290.2	8636.2	9179.4	11450.6
Kharif farming	58211.6	44931.9	53151.2	54500.9
Livestock	2657.7	2297.2	1782.5	2386.8
Agricultural wage labour	956.1	1057.4	1078.5	1003.7
Non-farm wage labourer	12479.9	18259.7	16428.6	14497.7
Salary/contractual	9649.4	7822.1	8793.4	9102.0
Business	5154.7	5089.6	6077.7	5355.1
Pension	1500.6	1549.4	1254.5	1453.2
Remittance	1321.4	1307.5	960.1	1235.4
Total income	109792.6	93845.8	103986.2	105399.0

Table 31: District-Wise Sources of Household Income (Rupees per Household per Year)

Source of Income	Bargarh	Deogarh	Ganjam	Jharsuguda	Kalahandi	Koraput	Nabarangpur	Sambalpur	Total
Farming	100811	67725	53116	66300	74446	51805	69126	65994	70365
Rabi farming	22323	13611	7659	8084	13287	6159	6665	11495	11451
Kharif farming	71005	49997	39230	55998	57519	45219	58280	47289	54501
Livestock	3098	2015	486	847	110	4470	3544	2133	2387
Agricultural wage labor	1691	1321	821	367	961	1037	471	1108	1004
Non-farm wage laborer	6849	12693	9346	19290	10714	19904	21152	14200	14498
Salary/contractual	13296	15793	3129	28569	9911	1284	5330	9550	9102
Business	8250	12107	7973	5450	4708	1339	1675	8035	5355
Pension	739	0	3018	3050	1088	1266	1876	1717	1453
Remittance	354	0	11402	0	1556	0	569	519	1235
Total Income	135088	111655	89291	123872	103494	81105	103743	103255	105399

The district-wise distribution of household income per year is summarized in Table 31. The analysis indicates variations in total household income across districts, with Bargarh reporting the highest annual income (₹ 135,087), followed by Deogarh (₹ 111,655) and Jharsuguda (₹ 123,873). Farming remains the primary source of income across all districts, contributing the highest share in Bargarh (74%) compared to other districts.

Income from *Rabi* farming was also observed to be the highest in Bargarh (₹ 22,323), followed by Deogarh (₹ 13,611) and Kalahandi (₹ 13,287), reflecting variations in post-rainy season agricultural income. Conversely, Koraput (₹ 81,105) and Ganjam (₹ 89,291) recorded the lowest total household incomes, with farming playing a comparatively smaller role in total earnings.

Non-farm wages and salary/contractual employment represented significant portions of household income in certain districts, highlighting the role of livelihood diversification. Jharsuguda had the highest share of salary/contractual income (₹ 28,569), while Nabarangpur and Koraput had relatively higher shares of non-farm wages. The contributions of livestock and fisheries to household income remained minimal across all districts. These findings underscore regional disparities in income sources, influenced by agricultural productivity, employment opportunities, and access to alternative livelihoods.

8.7 Household Dietary Diversity

Dietary diversity is a key determinant of household food security and nutritional well-being, reflecting access to a variety of food groups essential for a balanced diet. The analysis of dietary diversity among different household categories (Figure 8) indicates a notable variation across beneficiary, control-1, and control-2 groups. The proportion of households with low dietary diversity is higher among control-1 (24.0%) and control-2 (21.6%) groups, whereas beneficiary households report a significantly lower incidence (13.5%). In contrast, the proportion of households with high dietary diversity is greater among beneficiaries (17.7%) compared to control-1 (11.8%) and control-2 (13.8%). The majority of households fall within the medium dietary diversity category, with the highest share observed among beneficiary households (68.8%).

These findings suggest that interventions in agricultural productivity, income enhancement, and nutrition awareness contribute to improved dietary diversity. Beneficiary households, who have participated in the project, exhibit better dietary diversity, potentially due to increased crop diversification, improved household incomes, and enhanced market access for a wider range of food products. Additionally, access to nutrition-sensitive agricultural practices, extension services, and capacity-building initiatives has played a role in influencing dietary choices. Moreover, promoting household-level nutrition education and behavior change communication strategies can reinforce the importance of consuming a balanced diet, ensuring that improved agricultural productivity translates into better nutritional outcomes

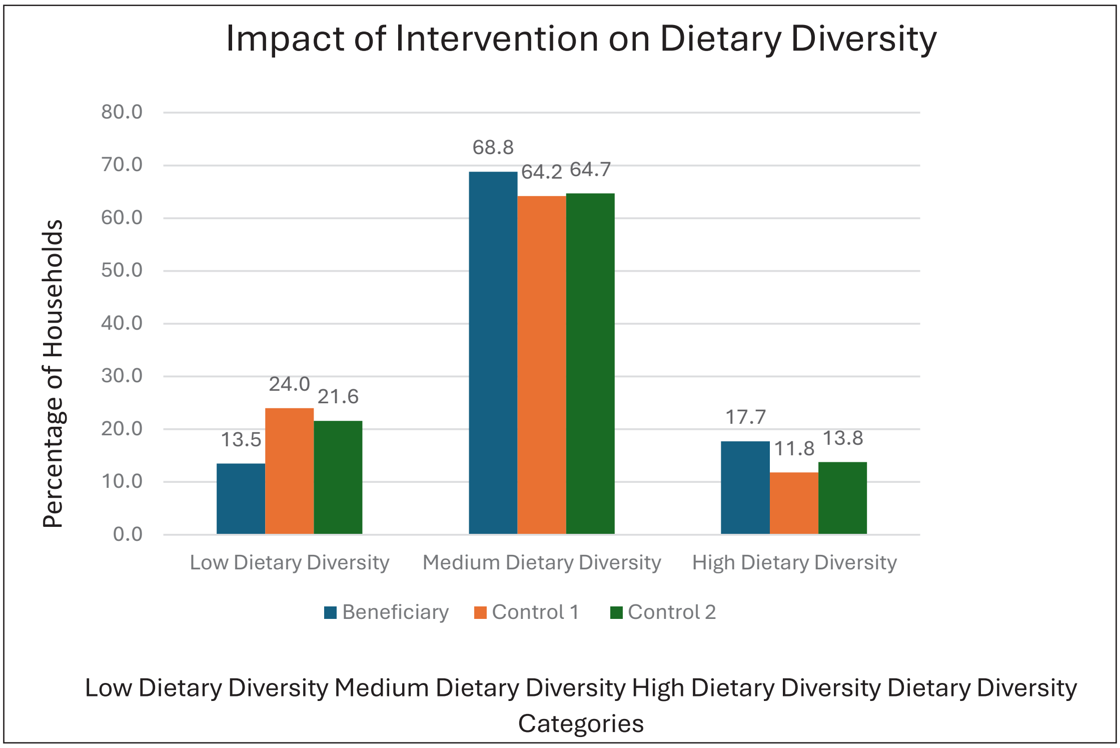


Figure 8: Impact of interventions on household dietary diversity

The Dietary Diversity Index (DDI) analysis presented in Table 32 illustrates variations in dietary diversity across different districts and farmer categories. Overall, the proportion of households classified under the "Medium" dietary diversity category is the highest (67.0%), followed by "Low" (17.4%) and "High" (15.7%). Beneficiary households exhibit a higher proportion in the "High" dietary diversity category (17.7%) compared to control-1 (11.8%) and control-2 (13.8%) households, suggesting a positive association between project interventions and dietary diversity improvement.

Table 32: District-Wise Distribution of Dietary Diversity Index (DDI)

	Dietary Diversity Index (DDI)											
	Beneficiary			**Control 2**			**Control 2**			**Total**		
District	**Low**	**Medium**	**High**	**Low**	**Medium**	**High**	**Low**	**Medium**	**High**	**Low**	**Medium**	**High**
Bargarh	4.5	68.5	27.0	10.0	76.7	13.3	16.5	69.6	13.9	8.3	70.2	21.5
Deogarh	16.3	60.0	23.8	30.0	40.0	30.0	17.5	52.5	30.0	18.6	55.0	26.4
Ganjam	2.4	78.8	18.8	0.0	100.0	0.0	0.0	78.1	22.0	1.4	80.7	17.9
Jharsuguda	1.7	81.7	16.7	15.0	65.0	20.0	20.0	67.5	12.5	10.0	74.2	15.8
Kalahandi	4.2	83.8	12.1	8.3	81.7	10.0	6.3	83.8	10.0	5.3	83.4	11.3
Koraput	34.4	52.2	13.5	42.6	55.7	1.6	19.8	75.3	4.9	33.9	58.5	7.7
Nabarangpur	28.8	62.1	9.1	44.1	47.5	8.5	51.3	32.5	16.3	35.9	53.7	10.5
Sambalpur	4.4	68.5	27.2	3.3	67.2	29.5	30.0	58.3	11.7	9.2	66.2	24.6
Total	13.5	68.8	17.7	24.0	64.2	11.8	21.6	64.7	13.8	17.4	67.0	15.7

District-wise analysis reveals that Ganjam, Jharsuguda, and Kalahandi have the highest percentage of households in the "Medium" dietary diversity category, while Nabarangpur and Koraput have a relatively higher proportion of "Low" dietary diversity households. Notably, Deogarh and Sambalpur districts exhibit a significant percentage of households with "High" dietary diversity.

To assess the nutritional status of women aged 18 to 49 years in the sample, the Minimum Dietary Diversity for Women (MDD-W) scores were estimated across three categories and are presented in Table 33. The findings indicate that the proportion of women meeting the minimum dietary diversity was significantly higher among the beneficiary group compared to control-1 and control-2 groups. The overall MDD-W value for the entire sample was estimated at 72.3%, suggesting a relatively moderate level of dietary diversity. At the district level, Bargarh and Sambalpur recorded the highest MDD-W scores, indicating better dietary diversity among women in these districts. In contrast, Koraput exhibited the lowest MDD-W value, highlighting potential nutritional deficiencies and dietary limitations. The observed variations across districts suggest that access to diverse food groups and nutritional awareness might play a critical role in shaping dietary patterns. These findings reinforce the importance of targeted nutrition interventions, particularly in districts with lower MDD-W scores, to improve dietary diversity and overall nutritional outcomes for women.

Table 33: Minimum Dietary Diversity for Women (MDD-W) Scores (% of Women Meeting MDD-W)

District	Beneficiary	Control-1	Control 2	Overall
Bargarh	91.8	75.0	94.4	91.5
Deogarh	76.2	80.0	70.6	74.4
Ganjam	72.7	82.0	65.0	71.4
Jharsuguda	87.5	77.0	71.4	81.3
Kalahandi	76.3	72.7	80.0	76.6
Koraput	41.7	47.4	50.0	45.6
Nabarangpur	68.0	42.9	28.6	49.1
Sambalpur	91.8	79.0	45.5	86.3
Total	78.7	64.6	64.3	72.3

Table 34: Daily Per Capita Pulse Consumption (Grams per Person per Day)

	Beneficiary			Control-1			Control 2			Overall		
District	Male	Female	Overall	Male	Female	Overall	Male	Female	Overall	Male	Female	Overall
Bargarh	51.9	51.9	51.9	49.2	52.3	49.7	41.3	50.0	44.5	48.9	51.5	49.8
Deogarh	39.0	42.6	40.4	45.6	34.5	42.3	37.2	43.5	40.7	39.7	42.1	40.7
Ganjam	51.7	49.5	51.1	43.2	41.7	42.8	44.8	42.0	44.6	48.6	47.7	48.4
Jharsuguda	39.4	49.9	42.2	37.8	43.3	38.9	32.9	27.7	31.5	37.0	41.2	38.1
Kalahandi	42.0	42.3	42.1	42.5	42.0	42.4	42.9	42.4	42.7	42.3	42.3	42.3
Koraput	27.7	33.8	29.2	30.1	31.6	30.8	30.8	32.7	31.1	29.2	32.5	30.1
Nabarangpur	36.6	37.1	36.7	30.3	19.1	28.8	31.1	25.6	29.2	34.6	31.1	33.9
Sambalpur	41.2	45.3	42.8	40.0	43.4	41.0	36.3	31.4	34.7	39.9	42.5	40.8
Total	40.4	44.2	41.5	38.4	36.2	37.8	36.8	37.7	37.1	39.2	41.2	39.8

The details about daily per capita consumption of pulses information were elicited from sample households and summarized in Table 34. The mean per capita consumption of pulses for the total sample was estimated at 39.8 gms/day which is far below the WHO recommended value (80 gms/day). Among the three categories, these values were slightly better in case of beneficiaries followed by control-1 and control-2 categories. These values clearly support the argument that the enhanced pulses production in their farm has not only promoted their per capita consumption but also their marketed surplus of pulses in the study area. The study sampled farmers are slowly perceiving the benefits of pulse production and consumption on their farms. The consistent efforts of the CPRFM will further motivate the farmers towards pulses production and consumption. Among study districts, the highest per capita values were observed in the case of Bargarh followed by Ganjam and Kalahandi districts.

9. Summary of Project Impacts on Sample Households

Table 35: Measured Impact of Project Interventions on Sample Households

Indicator	Beneficiary (N=1255)	Control-1 (N=416)	Control 2 (N=501)	Pooled (N=2172)
Agricultural and Land Use				
Average *Rabi* cropped area per household (acres)	1.4	0.7	0.7	1.1
Share of *Rabi* cropped area in total operational landholding (%)	46.1	32.6	24.7	39.1
Extent of *Rabi* land fallow (%)	53.9	67.4	75.3	60.9
Crop Productivity (Kg/Acre)				
Black gram productivity (kg/acre)	248.0	206.1	186.9	227.0
Green gram productivity (kg/acre)	214.8	177.9	167.7	205.4
Lentil productivity (kg/acre)	215.2	173.0	159.1	205.7
Chickpea productivity (kg/acre)	279.2	214.7	207.0	238.8
Mustard productivity (kg/acre)	344.0	294.4	258.8	328.7
Economic impact				
Average annual agricultural income per household (₹)	76,072.8	56,462.9	67,610.9	70,365.1
Average annual income from *Rabi* farming (₹)	13,290.2	8,636.2	9,179.4	11,450.6
Share of *Rabi* income in total farm income (%)	17.5	15.3	13.6	16.3
Average *Rabi* income per acre (Rs)	5,570.1	4,609.7	3,432.1	4,893.0
Food and nutrition security				
Household Dietary Diversity Index (DDI)	52.1	47.6	49.8	50.7
Minimum Dietary Diversity - Women (MDD-W) (% of women meeting MDD-W)	78.7	64.6	64.3	72.3
Per capita pulse consumption (grams/day)	41.5	37.8	37.1	39.8

10. Study Conclusions and Way Forward

The Comprehensive Project on Rice-Fallow Management (CPRFM) has demonstrated the transformative potential of science-led interventions in revitalizing underutilized agricultural ecosystems. By strategically promoting short-duration pulses and oilseeds across Odisha's rice-fallow lands, the initiative not only intensified land use but also catalysed measurable improvements in farm incomes, household nutrition, and women's economic empowerment. Beneficiary households cultivated a significantly higher proportion of their fallow land during the *Rabi* season and achieved substantial gains in crop productivity and profitability, particularly in green gram, black gram, chickpea, mustard, and lentil, outperforming both intra-village and inter-village control groups.

A distinctive strength of the CPRFM model lies in its precision targeting, enabled by GIS-based rice-fallow area identification and the integration of the Analytics for Decision Making and Agricultural Policy Transformation (ADAPT) system for real-time monitoring and adaptive management. The project's robust collaborative ecosystem, anchored by local NGOs, Farmer Producer Organizations (FPOs), Self-Help Groups (SHGs), and the Department of Agriculture and Farmers' Empowerment, Government of Odisha, ensured efficient last-mile delivery of interventions and fostered farmer ownership. Importantly, CPRFM catalysed a paradigm shift from subsistence *Rabi* farming to semi-commercial farming systems, as evidenced by increased market participation and significant improvements in household dietary diversity. Furthermore, the project underscored the critical intersection of gender, education, and productivity, with women-headed households exhibiting superior agronomic and economic outcomes, highlighting the importance of gender-intentional agricultural programming.

Yet, significant systemic barriers persist. **Over 60% of *Rabi*-capable land among non-beneficiaries remains fallow, primarily due to inadequate irrigation infrastructure, limited access to quality seeds, and pervasive wildlife damage.** Alarmingly, more than 60% of control group farmers continue to source seeds from unregulated village markets, exposing them to poor varietal quality and undermining potential productivity gains. These findings point to enduring structural weaknesses in Odisha's seed systems and rural infrastructure that must be urgently addressed.

To sustain and scale the demonstrated successes of CPRFM, the following pathways must be institutionalized:

1. **Land-type-specific area selection** must become the cornerstone of *Rab*i expansion efforts. GIS-advised land classification should be operationalized at the district and block levels to prioritize midland ecologies, where residual soil moisture and topography favor the cultivation of short-duration pulses and oilseeds. Tailored varietal packages, informed by localized soil and moisture profiling, must be promoted to maximize yield potential and climate resilience.

2. **Decisive strengthening of local seed ecosystems is imperative.** PPP models, FPOs, women-led SHGs, and certified community seed producers must be systematically supported to produce, aggregate, and distribute high-quality seeds on time at the last mile, thereby reducing dependency on informal and often substandard seed markets.

3. **Concerted effort to build gender-inclusive knowledge systems** is essential. Scaling targeted training programs for women farmers and enhancing their access to information, technologies, and markets will not only reduce gender disparities but also amplify the overall effectiveness of agricultural interventions.

4. **Market linkages for *Rabi* produce must be deepened.** FPOs should be empowered to serve as aggregation hubs, connecting farmers to structured markets, e-NAM platforms, and private buyers, thereby facilitating the transition from production-led to market-led intensification.

In conclusion, **the CPRFM experience offers a replicable and scalable blueprint for converting rice fallows into dynamic engines of agricultural growth, climate resilience, and nutritional security**. With sustained policy support, strategic program convergence, and targeted investments in land, water, seed, and knowledge systems, Odisha is uniquely positioned to lead India's next wave of sustainable *Rabi* intensification. The imperative is clear: to transition from pilots to permanent systems change, ensuring that every acre of rice fallow becomes a productive asset and a cornerstone of resilient rural livelihoods.

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INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS

About

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) is a pioneering non-profit organization focused on scientific research for development, committed to transforming dryland farming and agri-food systems. Working with global partners, ICRISAT develops innovative solutions to address hunger, poverty, and environmental degradation, benefiting 2.1 billion people across the drylands of Asia, Africa, and beyond.

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