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IMPACT ASSESSMENT OF CROP DIVERSIFICATION THROUGH AGRI-HORTI-BASED INTERVENTIONS IN TRIBAL AREAS OF CHHATTISGARH UNDER THE FARMERS FIRST PROJECT

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ABSTRACT
The present study was conducted under the Farmers FIRST Project in four tribal villages Maldongri, Khursipar, Bharritola and Chikhali of Mohla-Manpur-Ambagarh Chowki district in the southwestern part of Chhattisgarh, was carried out during 2025-26 to evaluate the impact of crop diversification through agri-horti-based interventions under upland farming conditions. The selected villages are predominantly rainfed, characterized by low cropping intensity (114%), mono-cropping of rice, low adoption of improved technologies and limited livelihood opportunities. A participatory approach involving farmers and scientists was adopted to introduce integrated crop production, horticulture and resource management technologies. Major interventions included line sowing of rice with improved weed management, diversification of upland rice into maize, pulses and vegetables, utilization of field bunds for pigeon pea and fruit crops, low-cost gravity drip irrigation for vegetable cultivation in wadi systems, and fruit plantation on field bunds. The interventions significantly enhanced crop productivity, farm profitability and livelihood opportunities. Line sowing of rice increased grain yield to 32.15 q ha^{-1} compared with 29.55 q ha^{-1} under transplanting and 20.96 q ha^{-1} under broadcasting, while generating the highest net income (72,535 Rs/ha) with a Benefit ratio of 1:3.6. Crop diversification under upland conditions improved yields of maize (42.38 q ha^{-1}), green gram (9.84 q ha^{-1}), black gram (8.54 q ha^{-1}), brinjal (198.78 q ha^{-1}) and cowpea (84.62 q ha^{-1}), resulting in higher net returns and improved economic efficiency. Utilization of field bunds through pigeon pea and papaya increased yields by 32.8% and 66.9%, respectively, with corresponding improvements in profitability. Similarly, low-cost gravity drip irrigation enhanced vegetable yields by 14–25%, increased net income and improved Benefit ratios across all vegetable crops. Fruit plantation on field bunds, particularly papaya, further improved productivity (43.2%), income (54.1%) and land-use efficiency. The study demonstrated that agri-horti-based crop diversification effectively transformed traditional rice-based upland farming into a more productive, diversified and climate-resilient production system. The integrated interventions improved cropping intensity, resource-use efficiency, nutritional security and year-round employment while strengthening farmer–scientist interaction and technology adoption. The findings indicate that participatory agri-horti models have considerable potential for enhancing income, livelihood security and sustainable agricultural development in tribal rainfed regions of Chhattisgarh and similar agro-ecological situations.

KEYWORDS: Farmers FIRST Project, crop diversification, Agri-horti system, upland farming, tribal agriculture, integrated farming system, wadi cultivation, livelihood security.

INTRODUCTION
Indian agriculture has responsibility of providing national as well as household food and nutritional security to its teeming millions in a scenario of plateauing genetic potential in all major crops and declining productivity of rainfed areas. A mismatch between the national food grain production and requirement has already crept into the system, which is further widening. Simultaneously, the demand for high-value commodities such as; fruits, vegetables, livestock products, fish, poultry etc., is increasing faster than food grains (Dalal and Shankar., 2022). Livestock has traditionally been an integral part of farmers' household, as it plays an important role not only in the farm production but also in augmenting rural economy and in recycling of farm wastes (FAO, 2019). It is a major source of supplementing family incomes and generating gainful employment in the rural sector, particularly among the landless, small and marginal farmers and farm women (Anuja et al., 2020) Declining share of agriculture in gross domestic product, contracting average size of landholding and increasing number of operational holdings are the serious problems of Indian agriculture. Declining size of landholdings without any alternative income augmenting opportunity is resulting in fall of farm income, and causing agrarian distress. A large number of smallholders have to move to non-farm activities to augment their incomes. Research efforts so far have paid dividends, but mainly through medium and large farm holders. However, under the changing

scenario a paradigm shift in research is inevitable with more focus towards small and marginal holders (Yadav and Kumar. 2023).

In Chhattisgarh, traditionally rice and rice-based farming systems are practiced. The farmers are also rearing animals with rice farming but they are unproductive owing to local breed, poor draft power, low milk yield and non-availability of forage. Fish is grown by the farmers in ditches and ponds. Upland crops like green gram, black gram, peanut, pigeon pea is grown in upland. Since, majority of farmer adopting local varieties of crops with low input use resulting poor productivity and income (Singh et al., 2024). In the state, farmers are engaged for 4-months in rice farming thereafter majority of rain fed farmers have no on-farm employment opportunities. Out of 47.8 lakh ha cropped area during kharif season, rice occupy 3.90 million ha (>72%) area whereas only 1.61 million ha (34%) is cropped during rabi season. Seventy percent of rabi crops are grown under rainfed condition in which one-third is shared by Lathyrus as relay crop (utera) with poor yield (<2 q/ha). The productivity of rainfed rabi crops depend on seasonal rainfall, distribution and amount of moisture in the soil profile at planting time. Seasonal rainfall in the region is very scanty but nearly 3.00 mha (63%) cultivated area in the state are under heavy soils (Alfisols, vertisols and alluvial) which have considerable plant extractable soil moisture (200-300 mm) after harvest of rice to grow a rainfed rabi crop (Mooventhan et al., 2026).. However, the region receives 1200-1600 mm rainfall annually, sufficient to raise reasonable livelihood but due to lack of awareness, alternate technological options, stray cattle and lack of motivation, the major area remains fallow after rice causing insecurity for almost two-third part of the year. The region has a large number of small and marginal farmers (< 2 ha), approximately 76%, but they own hardly 34% of the cultivable land. The land holdings are not only very small but highly fragmented. Therefore, the future of sustainable agriculture growth and food security in India depends on the performance of small and marginal farmers. Farmer is the client of technology developed by the scientist at remote place with hypothesis that it will be adopted by the client. The researches aim at generating useful technologies meant for the development of ultimate users but the challenging situation regarding adoption of the technologies generated by situation. It is estimated that about 30% of the available technologies are adopted by the farmers (Ramya et al., 2017). Research on farmer field jointly by farmer and scientist will certainly be adoptable or otherwise rejected for further refinement. Farmer-participatory research (FPR) can help improve the effectiveness of technology development, raise adoption rates, and increase the payoff to agricultural research. Technologies that have been developed with involvement resource-poor households can have large recommendation domains.

The present study was undertaken with the objectives of assessing the impact of Agri-Horti-based interventions on crop diversification and cropping pattern of tribal farmers under upland conditions; evaluating the effect of these interventions on crop productivity, farm income, employment generation and livelihood security of tribal farmers; identifying and assessing the adoption level and effectiveness of suitable Agri-Horti technologies and farming systems under upland conditions; imparting need-based training and enhancing the knowledge, skills and awareness of tribal farmers regarding crop diversification and sustainable Agri-Horti-based farming systems; strengthening farmer-scientist interaction and assessing farmers' feedback, perception and satisfaction regarding the introduced Agri-Horti technologies; identifying economically viable, socially acceptable and agro-ecologically suitable Agri-Horti-based technological interventions and developing replicable models for tribal upland farming; assessing the role of Agri-Horti-based interventions in enhancing farm women's participation, reducing drudgery, generating additional income and improving livelihood security; and studying the constraints faced by tribal farmers in the adoption of crop diversification and Agri-Horti-based interventions and suggesting suitable strategies for their wider dissemination (Bhat et al., 2024).

METHODOLOGY OF CASE STUDY:

The present case study was undertaken to assess and compare the performance and economic effectiveness of different crop and horticulture technologies under farmers' field conditions. The study focused on the implementation of selected crop and horticulture modules at the farmers' level and the subsequent comparison of the technologies already being practiced in the area with those recommended by agricultural scientists. The ICAR-initiated Farmer FIRST (Farm, Innovations, Resources, Science, and Technology) Programme, designed to address the evolving challenges encountered by farmers across the nation, is driven by a vision to empower them through research-backed, innovative solutions. The project aims to bridge the gap between scientific knowledge and practical on-field agricultural applications. The methodology was designed to evaluate the extent to which the recommended technologies could improve crop performance, productivity, profitability, and overall farm-level outcomes. Initially, the major crops and horticultural crops commonly grown in the selected area were identified. Information regarding the existing production practices followed by farmers was collected through field visits, interaction with farmers, and observation of their prevailing cultivation practices. These existing practices were considered as the existing farmer technology, representing the conventional methods generally followed in the area. Following this, suitable crop and horticulture modules based on scientific recommendations were introduced and demonstrated in farmers' fields. The modules included appropriate production practices and other recommended technological interventions relevant to the respective crops and farming situations. The recommended technologies were implemented under actual farmers' field conditions so that their performance could be assessed under practical and representative situations rather than only under experimental conditions.

After implementation, a comparative assessment was carried out between the existing technology and the scientist-recommended technology. The comparison was made using a set of predefined performance and economic indicators developed for evaluating the different technologies. Performance indicators were used to assess the biological and production-related outcomes of the technologies, while economic indicators were used to determine their financial feasibility and profitability for farmers. The major performance indicators considered in the assessment included crop productivity/yield, growth and production performance, quality of produce, and other crop-specific parameters, wherever applicable. Economic indicators included cost of cultivation, gross return, net return, and Benefit–Cost (B:C) ratio

(Kaushal and Jain.,2023). These indicators provided a common basis for comparing the technologies across different crop and horticulture modules. Wherever required, the indicators were calculated using field-level data collected from the participating farmers.The data related to input use, cultivation practices, yield, input costs, labour requirements, and returns were recorded during the implementation of the modules. The cost of cultivation was estimated by considering the major variable inputs and other relevant production expenses. Gross returns were calculated based on the quantity of produce obtained and the prevailing/realized market price. Net returns were determined by deducting the total cost of cultivation from the gross returns, while the B:C ratio was used to assess the economic efficiency of the respective technology (Das et al.,2014 . Finally, the performance and economic indicators of the existing and recommended technologies were compared to determine the relative advantage of the scientist-recommended interventions. The comparative results were used to identify technologies that demonstrated better production performance, higher profitability, and greater economic feasibility under farmers' field conditions. Thus, the methodology provided a systematic framework for evaluating the effectiveness of crop and horticulture modules and for identifying technologies with greater potential for adoption and scaling among farmers in the study area.

Mohla-Manpur-Ambagarh Chowki district is one of the tribal districts of Chhattisgarh state and nearly 80 km away towards west from Raipur capital of the state. Four villages namely Maldongri, Khursipar, Bharritola and Chikhali were selected in the project. These villages are nearly 65 km away from Rajnandgaon district headquarters. Geographical area of the four-village cluster is 955.27 ha with 1098.64 ha Culturable area. Irrigated area is only 12.5% against 30% in the state. Mostly mono cropping of rice is prevalent in the cluster of villages and cropping intensity is 114%. Farmers are rearing large number of animals and birds as alternate livelihood activity. There is very good scope of lac culture in the villages owing to availability of kusum, palas and ber as host plants.

Demography and Geography of study area

Farm families: The selected area is dominated with tribal farmers. Total population of the cluster is 1952 in which ST and SC represents 55.95 and 6.4% in the cluster. There are 431 farm families are there in the four villages. Marginal and small farm families represent 114 and 96 in the total farm families of the cluster.

Table 1: Geographical area and basic information of the adopted village cluster

Adopted Villages	Geographical area (ha)	Culturable area(ha)	Forest area (ha)	Irrigated area (%)	Cropping intensity (%)	Tractor	Cow	Buffalo	Goat	Backyard poultry	Pig	Literacy (%)	Fertilizer use (kg/ha)	Trees for lac culture
1. Maldongri	377.85	402.56	8	5	108	2	101	6	108	210	0	82	41	561
2. Khursipar	174.97	226.41	13	10	115	4	200	8	231	312	0	78	49	510
3. Bharritola	183.11	202.78	3	19	113	2	100	3	20	112	0	85	42	901
4. Chikhali	219.34	266.89	2	16	120	7	250	18	256	131	0	83	35	1250
Total	955.27	1098.64	26	12.5	114	15	651	35	615	765	0	82	41.75	3222

Table 2: Population of selected villages and categories of farmers

Villages	Population (%)					Categories of farmer				
	ST	SC	OBC	Gen	Total	Big	Medium	Small	Marginal	Total
1. Maldongri	78.3	4.1	2.1	0	81.8	05	06	12	18	41
2. Khursipar	53.4	2.4	2.2	0	58	07	12	22	39	80
3. Bharritola	47.4	14.7	0.2	0	62.3	02	18	26	22	68
4. Chikhali	44.7	4.4	3.2	0.9	53.2	07	22	36	35	100
Total	55.95	6.4	1.92	0.22	63.82	21	58	96	114	289

Crops and cropping: Rice is grown in 98% area during kharif season. Wadi cultivation (kitchen garden) represents 0.6% area of the kharif season. Cropping intensity of the area is 114%. Lathyrus, wheat, chickpea and field pea are major rabi crops in the cluster amongst the farmers

Table 3: Existing crops grown by farmers in different villages

Villages	kharif crop area (ha)						Rabi crop area (ha)				
	Rice	Other cereals	Oilseed	Pulses	Vegetable in wadi	Total	Wheat	Chickpea	Field pea	Lathyrus	Total
1. Maldongri	102.45	1	0	0	0.23	103.68	0.12	4	0	0.11	4.23
2. Khursipar	112.3	0	3.1	0	5.7	121.1	0.23	2.1	0	2.89	5.22
3. Bharritola	115.46	0	0	0	0.89	116.35	0.11	3.6	0	3.79	7.5
4. Chikhali	156.48	3	5.2	0.11	2.1	166.89	0.52	4.6	1	3.5	9.62
Total	486.69	4	8.3	0.11	8.92	508.02	0.98	14.3	1	10.29	26.57

RESULTS AND DISCUSSION:

1. Demonstrated Technology under Crop based module : Line sowing of rice with herbicide and sowing of rabi crops in rainfed and irrigated condition after rice

The demonstrated technology of line sowing of rice integrated with herbicide application followed by rabi crop cultivation proved to be an effective approach for improving rice-based cropping systems in mid and lowland areas. The intervention addressed major production constraints such as poor yield, delayed harvesting, weed infestation, terminal drought, and rice fallows. Line sowing facilitated better crop establishment, efficient weed management, and timely crop operations, while the use of pre- and post-emergence herbicides reduced weed competition (Baishya et al., 2019). The technology also enabled the cultivation of rabi crops using residual soil moisture or available irrigation, thereby increasing cropping intensity. Overall, the intervention resulted in an expected 20–30% increase in rice yield over the traditional broadcasting method, improved resource-use efficiency, and enhanced farmers' productivity and income, demonstrating its suitability for sustainable rice-based farming systems shown in Table 4 (a) & Fig 1.

Table 4 (a) : Description of line sowing with herbicide application technology under Crop based module

1. Name of technology	Line sowing of rice with herbicide and sowing of rabi crops in rainfed and irrigated condition after rice
2.Farming situation	Mid and low land
3. Problem	Poor yield, delayed harvesting, threat of terminal drought and fallow after rice in traditional broadcast seeded rice
4. Potential solution	Alleviating reproductive drought in rice and possibility of double cropping under rainfed condition.
5. Nature of intervention	Dry/ moist line sowing of rice and use pre and post emergence herbicide for weed management followed by sowing of rabi crop under irrigated and in rainfed -residual soil moisture in heavy soils-cropping in rice fallow
6. Source of technology	IGKV, Raipur
7. Expected output	Rice yield increase by 20-30% over traditional biasi method of rice cultivation (adopted in > 70% area during kharif season)
8. Area (ha)	3.6
9. No. of farm families	15
10. Critical input	Seed, fertilizer, weedicide and seed of Rabi crops
11. Crop and variety	Paddy (Vikram-TCR)
12. Cost of each intervention	0.30 Lakh

The performance evaluation indicated in Table 4 (b) that line sowing of rice with a seed drill was superior to the existing farmers' practices of transplanting and broadcasting. The intervention recorded the highest grain yield (32.15 q/ha) compared to 29.55 q/ha under transplanting and 20.96 q/ha under broadcasting. Similarly, straw yield (49.0 q/ha) was also higher than that obtained through transplanting (39.71 q/ha) and broadcasting (42.15 q/ha). The cost of cultivation under the intervention (27,130 Rs /ha) was lower than transplanting (33,110 Rs /ha), while the net income (72,535 Rs /ha) and benefit-cost ratio (1:3.6) were substantially higher than both transplanting (1:2.7) and broadcasting (1:2.4).Farmers expressed positive feedback, stating that the technology enabled timely sowing, reduced labour requirements, and improved profitability (ICAR.,2010). However, they also noted that the technology becomes difficult to implement under heavy rainfall conditions. Overall, the results demonstrate that line sowing with a seed drill is a more productive, economical, and farmer-friendly technology for sustainable rice cultivation (Prasad et al., 2025.

Table 4 (b) Performance Indicators

A.	**Technical Observation**	**Farmers practice**	**Intervention**
i.	Yield (q/ha)		
a.	Grain (q/ha)	29.55 (transplanting method) 20.96 (broadcasting method)	32.15 (line sowing with seed drill)
b.	Straw (q/ha)	39.71 (transplanting method) 42.15 (broadcasting method)	49. (line sowing with seed drill)

ii.	Total water use (m3ha -1 water)/Water productivity (kg grain m-3)/Water use efficiency (q grain/ha/cm) *In case of Ridge and Furrow/BBF/Laser land	NA	NA
B.	Economic indicators		
i.	Cost of cultivation (Rs./ha)	33110/- (Transplanting method) 26700/- (Broadcasting method)	27130/- (Line sowing with seed drill)
ii.	Net income (Rs./ha)	58495/- (transplanting method) 38276/- (Broadcasting method)	72535/-
iii.	B:C ratio	1:2.7 (transplanting method) 1:2.4 (Broadcasting method)	1:3.6 (Line sowing with seed drill)
C.	Farmers reaction	This is very good technology, timely sowing of rice and solve the labour problem but after heavy rain is could not perform	

Demonstration of line sowing of paddy (Vikram-TCR) through seed drill

Demonstration of line sowing of rice (Vikram-TCR) through transplanting method

Fig 1: Demonstration of line sowing of paddy in the farmer fields of the project area

2. Demonstrated Technology under Crop based module : Crop diversification of rice with maize, pulses and vegetable in upland condition

The demonstrated technology on crop diversification of upland rice with maize, pulses, and vegetables was introduced to overcome the challenges of frequent drought and low productivity in upland rice ecosystems. Replacing sole upland rice cultivation with drought-tolerant crops such as maize, green gram, black gram, cowpea, and brinjal under rainfed or protective irrigation conditions improved the resilience of the farming system. The diversification strategy reduced the risk of crop failure due to erratic rainfall, ensured more stable production, and enhanced resource-use efficiency (IGKV, 2019). The intervention provided assured yields of maize and pulses even under fluctuating rainfall conditions, while vegetable cultivation generated higher and more return in Table 5 (a) & Fig 2.

Table 5 (a) : Description of Crop diversification technology under Crop based module

1. Name of technology	Crop diversification of rice with maize, pulses and vegetable in upland condition
2.Farming situation	Upland
3. Problem	Upland rice usually suffers from drought and produces low yield
4. Potential solution	Alleviating drought under upland condition with diversified cropping
5. Nature of intervention	In place of upland rice, maize, green gram, black gram or vegetable like brinjal and cowpea will be grown under rainfed or protective condition
6. Source of technology	IGKV, Raipur
7. Expected output	Assured crop of maize and pulse even after fluctuating rainfall condition and remunerative income from vegetables compared to upland rice
8. Area (ha)	0.40
9. No. of farm families	60
10. Critical input	Seed, fertilizer, insecticide
11. Crop and variety	Maize (SIRI-5546), Green gram (Sikha), Black gram (Indira urd), Cow pea (Lalita), Brinjal (No.41)
12. Cost of each intervention	0.55 Lakh

The table 5 (b) clearly depicts that the performance evaluation demonstrated that crop diversification with maize, pulses, and vegetables significantly outperformed the existing farmers' practice in terms of productivity and profitability. Under the intervention, the yields of all crops increased substantially, with maize yielding 42.38 q/ha compared to 35.23 q/ha, green gram 9.84 q/ha compared to 7.20 q/ha, black gram 8.54 q/ha compared to 6.98 q/ha, brinjal 198.78 q/ha compared to 168.45 q/ha, and cowpea 84.62 q/ha compared to 60.34 q/ha under farmers' practice. Although the cost of cultivation increased slightly due to improved management practices, the intervention generated significantly higher net income and better benefit-cost (B:C) ratios across all diversified crops. Farmers also reported higher yields, improved water-use efficiency, and the ability to bring more area under irrigation. Overall, the results indicate that crop diversification is a climate-resilient and economically viable technology that enhances productivity, profitability, and sustainable livelihood security in upland farming systems technology that enhances productivity, profitability, and sustainable livelihood security in upland farming systems (Mooventhan et al., 2019).

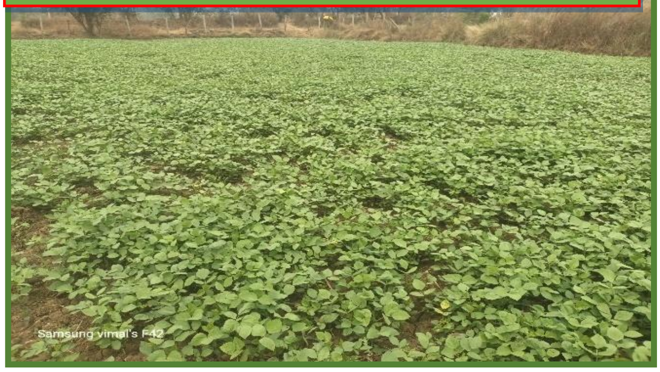
Table 5 (b): Performance Indicators

A.	Technical Observation	Farmers practice	Intervention
i.	Yield (q/ha)		
	1. Maize crop (hybrid)	35.23	42.38
	2. Green Gram	7.20	9.84
	3. Black Gram	6.98	8.54
	4. Brinjal	168.45	198.78
	5. Cow Pea	60.34	84.62
ii.	Total water use (m3ha -1 water)/Water productivity (kg grain m-3)/Water use efficiency (q grain/ha/cm) *In case of Ridge and Furrow/BBF/Laser land leveling/Zero tillage	NA	NA
B.	Economic indicators		

i.	Cost of cultivation (Rs./ha)	Maize (Broadcasting method) 21456/- Moong 15150/- Black Gram 16340/- Brinjal 88976/- Cowpea 78945/-	Maize (line sowing) 25467/- Moong 20145/- Black Gram 18790/- Brinjal 98794/- Cowpea 92879/-
ii.	Net income (Rs./ha)	Maize 38345/- Moong 22290/- Black Gram 18560/- Brinjal 247924/- Cowpea 162415/-	Maize 46579/- Moong 31023/- Black Gram 23910/- Brinjal 298766/- Cowpea 239686/-
iii.	B:C ratio	Maize 1:2.7 Moong 1:2.4 Black Gram 1:2.1 Brinjal 1:3.7 Cowpea 1:3.0	Maize 1:2.8 Moong 1:2.5 Black Gram 1:2.2 Brinjal 1:4.0 Cowpea 1:3.6
C.	Farmers reaction	Higher yield, saving of water and bring more area under irrigation	

Demonstration of Maize (SIRI-4456)

Demonstration of Black gram (kota-4)



Demonstration of Green gram (IPM -410-3)

Demonstration of Brinjal crop (Nisha)

Fig 2 : Demonstration of Maize, Black gram, Green gram and Brinjal in the farmer fields of the project area

3. Demonstrated Technology under Crop based module : Utilization of field bunds through fruit crops, pulses and oil seed crops

The intervention demonstrated that field bunds can be effectively utilized for crop diversification and income enhancement. Nearly 10% of the cultivated area is generally occupied by field bunds, which often remain unutilized by farmers. The integration of pigeon pea (Arhar), sesame (Til), papaya and mango fruit crops on field bunds provides an opportunity to generate additional returns from otherwise unproductive spaces. The technology also promotes efficient utilization of land resources without substantially affecting the main crop area. Adoption of suitable crops on bunds can enhance cropping intensity, farm diversification and overall productivity. Fruit crops such as papaya and mango may provide additional long-term economic benefits, while pigeon pea and sesame offer seasonal returns shown in Table 6 (a)

& Fig 3. The intervention involving 75 farm families indicates its potential for wider adoption among small and marginal farmers. Overall, the technology can contribute to increased farm income, improved resource-use efficiency and livelihood strengthening. Thus, field-bund-based crop diversification represents a promising approach for sustainable and profitable farming systems (IGKV, 2020).

Table 6 (a) : Description of Utilization of field bunds under Crop based module

1. Name of technology	Utilization of field bunds through a fruit crops, Arhar and Til
2. Farming situation	Field bunds
3. Problem	About 10 % area comes under field bunds. Farmers are not utilizing the field bunds
4. Potential solution	Utilization of field bunds through highly remunerative crops like Pigeon pea, Til, .Mango and Papaya
5. Nature of intervention	During the main season (kharif) sowing of Arhar ,Til and fruit crops on bunds for getting higher income and crop diversification
6. Source of technology	IGKV, Raipur
7. Expected output	Crop diversification and intensification getting higher income in different enterprises
8. Area (ha)	On Bunds
9. No. of farm families	75
10. Critical input	Seed, fertilizer, insecticide
11. Crop and variety	Pigeon pea (Chhattisgarh arhar-1), Papaya (Red leady), Mango (Dasheri),
12. Cost of each intervention	0.30 Lakh

The performance indicators clearly demonstrate in Table 6 (b) the technical and economic benefits of utilizing field bunds for crop diversification. Under the intervention, pigeon pea yield increased from 8.36 to 11.10 q/ha, representing an improvement of approximately 32.8% over farmers' practice. Similarly, papaya yield increased substantially from 8.92 to 14.89 q/ha, showing an increase of about 66.9%. The higher yield under the intervention indicates the effectiveness of improved crop management and utilization of field bunds (Mooventhan et al., 2022).

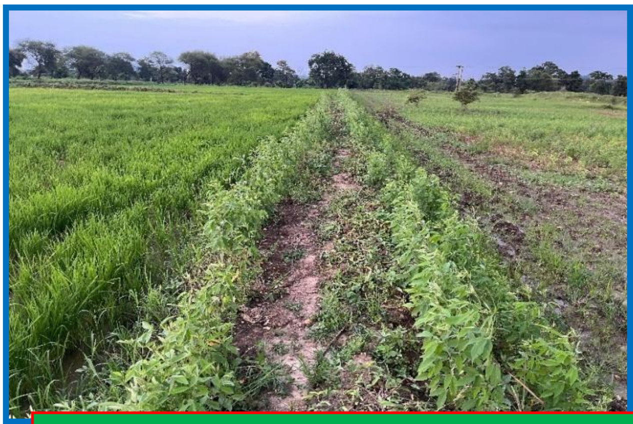
Economically, the cost of cultivation increased from 21,897 to 23,880 Rs /ha in pigeon pea and from 9,370 to 11,620 Rs /ha in papaya. However, the increase in cultivation cost was accompanied by considerable improvement in net income. Net income from pigeon pea increased from 40,803 to 59,640 Rs /ha, while papaya net income increased from 12,930 to 25,605 Rs /ha. This represents an increase of approximately 46.2% and 98.1%, respectively.

The Benefit:Cost ratio also improved from 1:2.8 to 1:3.4 in pigeon pea and from 1:2.3 to 1:3.2 in papaya, indicating better economic viability of the intervention. Mango data under intervention were not available (NA), therefore, comparative interpretation could not be made for this crop. Overall, the findings indicate that field-bund utilization through suitable crops can enhance productivity, net returns and profitability while making better use of otherwise underutilized farm space. The positive farmers' response further suggests that the technology has good potential for income enhancement, crop diversification and sustainable intensification of smallholder farming systems (Mooventhan et al., 2023)..

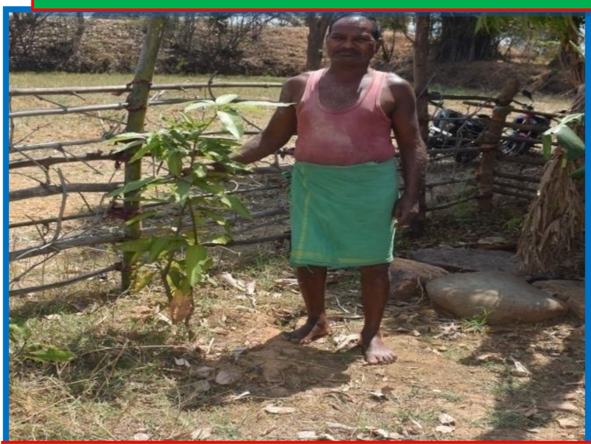
Table 6 (b): Performance Indicators

A.	Technical Observation	Farmers practice	Intervention
i.	Yield (q/ha)		
	1. Pigeon pea	8.36	11.10
	2. Papaya	8.92	14.89
	3. Mango	9.0	NA
ii.	Total water use (m3ha -1 water)/Water productivity (kg grain m-3)/Water use efficiency (q grain/ha/cm) *In case of Ridge and Furrow/BBF/Laser land leveling/Zero tillage	NA	NA
B.	Economic indicators		
i.	Cost of cultivation (Rs./ha)	Arhar 21897/- Papaya 9370/- Mango 12940/-	Arhar 23880/- Papaya 11620/- Mango NA

ii.	Net income (Rs./ha)	Arhar 40803/- Papaya 12930/- Mango 32060/-	Arhar 59640/- Papaya 25605/- Mango NA
iii.	B:C ratio	Arhar 1:2.8 Papaya 1:2.3 Mango 1:3.4	Arhar 1:3.4 Papaya 1:3.2 Mango NA
C.	Farmers reaction	Very good intervention for additional income and space utilization	



Utilization of field bund through cultivation of Arhar (Chhattisgarh Arhar-1)



Utilization of field bund through Demonstration of Mango (Langra)

Utilization of field bund through Demonstration of Papaya (Red lady)

Fig 3 : Demonstration of Utilization of field bunds through fruit crops, oil and leguminous crops in the farmer fields

4. Demonstrated Technology under Horticulture based module : Performance of low-cost gravity drip irrigation system for vegetable cultivation

The horticulture-based module demonstrated the potential of a low-cost gravity drip irrigation system for vegetable cultivation in wadi-based farming systems. The intervention was designed to utilize the otherwise underproductive spaces within wadi areas ranging from 0.05 to 2.0 acres for vegetable production. The gravity-fed drip system, comprising a water tank placed at approximately 3–5 m height and connected with drip lines, provides a low-cost and efficient method of irrigation. A diversified range of vegetables, including brinjal, chilli, tomato, bitter gourd, sponge gourd, leafy vegetables and root crops, was proposed under the intervention. The technology is particularly relevant for tribal farmers because it facilitates vegetable production with limited water availability and comparatively low investment (Joshi et al.,2006). The intervention covered 25 farm families with a plot size of 0.1 ha, with seed, fertilizer, drip components and a water tank as critical inputs indicated in Table 7(a) & Fig 4. The adoption of diversified vegetable crops can improve nutritional security, dietary diversity and farm income. Furthermore, efficient application of water through drip irrigation can support better crop establishment and productivity under wadi conditions. The expected outcome of increased income from wadi cultivation indicates the potential of the technology to strengthen the livelihood opportunities of tribal farm households. Overall, the low-cost gravity drip irrigation system represents a resource-efficient, affordable and sustainable horticultural intervention for enhancing productivity, income and nutritional security in wadi-based farming systems (Bisen et al., 2025 a).

Table 7 (a) : Description of Performance of low-cost gravity drip irrigation system under horticulture based module

1. Name of technology	Performance of low-cost gravity drip irrigation system for vegetable cultivation in wadi
2. Farming situation	Wadi situation
3. Problem	Size of wadi ranged from 0.05 to 2 acres in the study area that remained unproductive or growing seasonal vegetables in part of the area and have scope to grow good crops for livelihood and nutritional security of tribal farmers
4. Potential solution	High yield of vegetables under wadi condition in drip irrigation
5. Nature of intervention	Brinjal, chilli, tomato, bitter gourd, sponge gourd, pan and leafy vegetable and root crop will be taken and irrigation will be given by putting a tank on 3-5 m height and drip will be connected for irrigation
6. Source of technology	IGKV, Raipur
7. Expected output	More income from wadi cultivation
8. Plot size/area (ha)	0.1
9. No. of farm families	25
10. Critical input	Seed and fertilizer, drip and water tank
11. Crop and variety	Brinjal (MAYA Green), chilli (Chadani), tomato (Abhilas), bitter gourd (Golu-15), sponge gourd (NS-441), and leafy vegetable
12. Cost of each intervention	0.50 Lakh

The performance indicators reveal that the low-cost gravity drip irrigation system substantially improved the productivity and economic performance of vegetable cultivation under the wadi-based farming system in Table 7 (b). The intervention resulted in higher yields in all the evaluated vegetable crops compared with farmers' conventional practices. The yield of brinjal increased from 156.12 to 178.36 q/ha (14.2%), while chilli yield increased from 96.24 to 111.12 q/ha (15.5%). Similarly, tomato yield increased from 212.36 to 250.45 q/ha (17.9%), and bitter gourd yield increased from 114.45 to 132.41 q/ha (15.7%). The highest relative improvement in yield was observed in sponge gourd (24.9%), followed by leafy vegetables (20.5%).The economic indicators also demonstrated the profitability of the intervention. Although the cost of cultivation increased slightly under the improved irrigation system, it was compensated by higher net returns. Net income increased from 2,16,394 to 2,58,263 Rs/ha in brinjal, from 2,86,206 to 3,35,505 Rs/ha in chilli, and from 2,11,055 to 2,67,523 Rs/ha in tomato. Likewise, net income under the intervention increased to 3,42,979 Rs/ha in bitter gourd 1,39,569 Rs/ha in sponge gourd and 3,62,063 Rs/ha in leafy vegetables.

The Benefit:Cost ratio further confirmed the economic viability of the technology, increasing to 1:3.6 in brinjal, 1:4.0 in chilli, 1:3.4 in tomato, 1:3.8 in bitter gourd, 1:3.1 in sponge gourd and 1:4.2 in leafy vegetables. The highest B:C ratio was recorded in leafy vegetables, followed by chilli and bitter gourd. Farmers' positive response indicated that the technology was useful for obtaining round-the-year green vegetables, improving household nutritional security and generating additional farm income. Overall, the findings suggest that low-cost gravity drip irrigation is an economically viable and technically effective intervention for enhancing vegetable productivity, profitability, nutritional security and livelihood opportunities of tribal farming households under wadi conditions (Bisen et al., 2025 b).

Table 7 (b): Performance Indicators

a.	Technical Observation	Farmers practice	Intervention
	Yield (q/ha)		
	1. Brinjal	156.12	178.36
	2. Chilli	96.24	111.12
	3. Tomato	212.36	250.45
	4. Bitter gourd	114.45	132.41
	5. Sponge gourd	65.78	82.14
	6. Leafy vegetable	112.68	135.78
b.	Economic indicators		
i.	Cost of cultivation (Rs./ha)	Brinjal 95846/- Chilli 98754/- Tomato 107485/- Bitter gourd 112456/- Sponge gourd 58794/- Leafy vegetable 98754/-	Brinjal 98457/- Chilli 108975/- Tomato 109922/- Bitter gourd 120456/- Sponge gourd 65781/- Leafy vegetable 112567/-

ii.	Net income (Rs./ha)	Brinjal 216394/- Chilli 286206/- Tomato 211055/- Bitter gourd 288119/- Sponge gourd 105656/- Leafy vegetable 295626/-	Brinjal 258263/- Chilli 335505/- Tomato 265753/- Bitter gourd 342979/- Sponge gourd 139569/- Leafy vegetable 362663/-
iii.	B:C ratio	Brinjal 1:3.2 Chilli 1:3.8 Tomato 1:2.9 Bitter gourd 1:3.5 Sponge gourd 1:2.7 Leafy vegetable 1:3.9	Brinjal 1:3.6 Chilli 1:4.0 Tomato 1:3.4 Bitter gourd 1:3.8 Sponge gourd 1:3.1 Leafy vegetable 1:4.2
c.	Farmers reaction	It is good technology for getting round the year green vegetable for the farm family and also fulfill the nutritional requirement	

Fig 4 : Demonstration low-cost gravity drip irrigation system for vegetable cultivation in wadi of farmer fields

5. Demonstrated Technology under Horticulture based module : Efficient Utilization of field bunds through fruit crop plantation

The technology, "Efficient Utilization of Field Bunds through Fruit Crop Plantation," aims to improve the productivity and profitability of farm holdings by utilizing the otherwise underused field bunds for fruit cultivation presented in Table 8 (a) & Fig 5. Field bunds generally constitute about 5–10% of the total cultivated area, but this space is often left unutilized by farmers. The intervention promotes plantation of papaya, mango, apple ber, guava and lemon on field bunds to generate additional income without substantially reducing the area under the main crop. The selected fruit crops and varieties, including Red Lady papaya, Dashehari, Amrapali, Langra and Alphonso mango, Miss India apple ber, Lucknow-49 and Allahabad Safeda guava, and lemon, provide diversification and opportunities for sustained returns. The intervention was implemented among 40 farm families, with fruit planting material as the major critical input. Besides improving land-use efficiency, fruit cultivation on bunds has the potential to enhance nutritional security and availability of fruits for farm households. It may also contribute to environmental benefits through increased perennial vegetation and better utilization of farm resources. The technology therefore represents a low-area, income-generating and resource-efficient approach to horticultural intensification. Overall, efficient utilization of field bunds through fruit crop plantation can strengthen farm income, crop diversification, nutritional security and sustainable livelihood opportunities among farming families (Panda., 2014).

Table 8 (a) : Description of efficient utilization of field bunds through fruit crop plantation under horticulture based module

1. Name of technology	Efficient Utilization of field bunds through fruit crop plantation
2. Farming situation	Field bunds
3. Problem	Field bunds contributed nearly 5-10 % area of the total land area but farmers are not utilizing these bunds for fruit cultivation
4. Potential solution	Planting of fruit plants in field bunds for getting additional income, nutritional security, better utilization of available space and save the environment
5. Nature of intervention	Better utilization of space, additional income from the same field and the same time and full fill the nutritional requirement of the farm family
6. Source of technology	IGKV, Raipur
7. Expected output	Additional income from the fruit plantation
8. Plot size/area (ha)	On Bunds
9. No. of farm families	40
10. Critical input	Fruit plants
11. Crop and variety	Papaya (Red lady), Mango (Dasheri, Amrapali,Langra, Alphonso), Ber (Apple ber) , Guava (Lakhnow -49, Allahabadi safeda , lemon
12. Cost of each intervention	1.0 Lakh

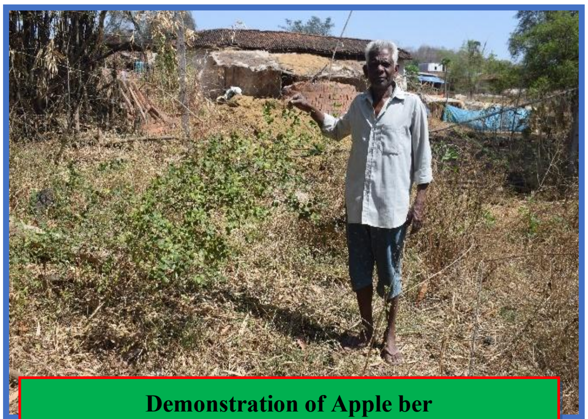
The performance indicators demonstrate the potential of fruit crop plantation on field bunds for improving productivity and economic returns through efficient utilization of otherwise underutilized farm space. Among the fruit crops evaluated, comparative yield data were available only for papaya. The yield of papaya increased from 93.24 to 133.50 q/ha under the intervention, representing an increase of approximately 43.2% over farmers' practice. This improvement indicates the effectiveness of improved planting material and management practices adopted under the field-bund-based fruit production system.The economic analysis further revealed that the cost of papaya cultivation increased from 58,975 to 70,457 Rs /ha /ha under the intervention. However, this additional investment was associated with a substantial increase in net income, which increased from 1,27,505 to 1,96,543 Rs/ha representing an improvement of approximately 54.1%. The Benefit:Cost ratio also increased from 1:3.1 to 1:3.7, indicating improved economic efficiency and profitability of papaya cultivation under the intervention in Table 8 (b).

For mango, guava, apple ber, jackfruit and lemon comparative intervention data for yield and/or net income were not available; therefore, a direct assessment of their productivity and profitability could not be made from the presented data. Nevertheless, the cost data indicate that the intervention involved relatively crop-specific investments, while fruit plantation on field bunds provides an opportunity to generate additional returns from land that otherwise remains underutilized. The very positive response of farmers regarding additional income and better utilization of available space further supports the practical acceptability of the technology (Singh., 2010). Overall, the findings suggest that field-bund fruit plantation, particularly papaya under the present dataset, can enhance productivity, net returns and profitability while improving land-use efficiency. The intervention therefore has considerable potential for crop diversification, nutritional security, additional income generation and sustainable intensification of smallholder farming systems (Petarek et al., 2016).

Table 8 (b): Performance Indicators

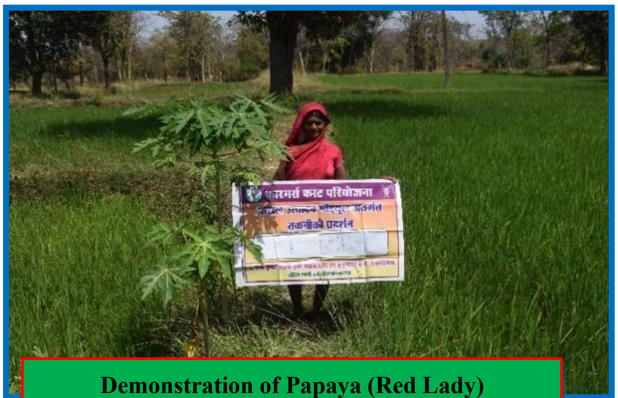
a.	Technical Observation	Farmers practice	Intervention

	Yield (q/ha)		
	1.Mango	28.3	NA
	2.Papaya	93.24	133.5
	3.Guava	34.8	NA
	4.Apple ber	NA	NA
	5.Jackfruit	122.12	NA
	6.Lemon	70.03	NA
b.	**Economic indicators**		
i.	Cost of cultivation (Rs./ha)	Mango 38380/- Papaya 58975/- Guava 42874/- Apple ber NA Jack fruit 98457/- Lemon 98754/-	Mango 33758/- Papaya 70457/- Guava 15789/- Apple ber 12478/- Jack fruit 13457/- Lemon 8794/-
ii.	Net income (Rs./ha)	Mango 74820/- Papaya 127505/- Guava 96326/- Apple ber NA Jack fruit 267903/- Lemon 251396/-	Mango NA Papaya 196543/- Guava NA Apple ber NA Jack fruit NA Lemon NA
iii.	B:C ratio	Mango 1:3.0 Papaya 1:3.1 Guava 1:3.2 Apple ber NA Jack fruit 1:3.7 Lemon 1:3.5	Mango NA Papaya 1:3.7 Guava NA Apple ber NA Jack fruit NA Lemon NA
c.	Farmers reaction	Very good intervention for additional income and space utilization	

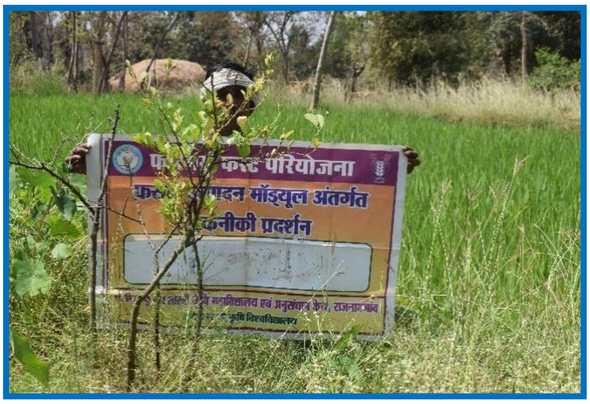

Demonstration of Apple ber

Demonstration of Mango (Alphanso)


Demonstration of Guava (Alhabadi safeda)



Demonstration of Papaya (Red Lady)



Demonstration of Lemon (Kagaji nibu)

Demonstration of Jackfruit

Fig 5 : Demonstration of utilization of field bunds through plantation of fruit crops in farmer fields

CONCLUSION

The Farmers FIRST Project demonstrated that crop diversification and agri-horti-based interventions can substantially improve the productivity, profitability and livelihood security of tribal farmers under upland and rainfed conditions of Rajnandgaon district, Chhattisgarh. The project successfully integrated improved crop production technologies, horticulture, efficient resource utilization and participatory farmer–scientist interaction to address the major constraints of low productivity, monocropping, seasonal unemployment and poor farm income prevailing in the selected tribal villages.The crop-based interventions clearly established that replacing traditional broadcasting and conventional cultivation practices with improved technologies resulted in significant gains in production and economic returns. Diversification of upland rice into maize, pulses and vegetables proved to be a climate-resilient and economically viable strategy. Improved varieties and scientific crop management increased yields of maize, green gram, black gram, brinjal and cowpea by approximately 15–40% over farmers' practices. Although improved technologies involved slightly higher cultivation costs, substantially higher net returns and better Benefit ratios were achieved, indicating that diversified cropping systems can effectively reduce production risks associated with erratic rainfall while enhancing farm profitability and livelihood resilience.

The horticulture-based interventions also produced encouraging results. Introduction of low-cost gravity drip irrigation for vegetable cultivation in wadi systems substantially increased yields of brinjal, chilli, tomato, bitter gourd, sponge gourd and leafy vegetables. Higher productivity translated into significantly greater net returns and Benefit ratios, while ensuring year-round availability of fresh vegetables for household consumption. Besides improving income, the intervention contributed to nutritional security through increased production and consumption of vegetables by tribal households. Similarly, plantation of fruit crops such as papaya, mango, guava, lemon and apple ber on field bunds demonstrated the potential for long-term income generation and better land-use efficiency. Papaya, for which comparative data were available, recorded a yield increase of over 43%, accompanied by substantial improvement in net income and profitability. Fruit-based interventions also created opportunities for environmental improvement through increased perennial vegetation and strengthened household nutritional security.Overall, the study demonstrates that agri-horti-based crop diversification is an effective strategy for improving the sustainability of tribal farming systems under upland and rainfed conditions. The integrated interventions enhanced cropping intensity, resource-use efficiency, productivity, profitability, nutritional security and resilience against climatic variability. The positive response of participating farmers further confirms the practical feasibility and acceptability of the technologies. Wider dissemination and scaling up of these integrated crop diversification and agri-horticultural models through suitable institutional support, capacity building and policy interventions can significantly contribute towards doubling farmers' income, sustainable natural resource management and livelihood security in tribal and rainfed regions of central India.

Conflict of Interest

The authors declare that they have no conflict of interest.

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