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On-Farm Research in integrated farming systems: Addressing challenges of small farms at the field level

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ABSTRACT

The ever increasing global population has intensified the pressure on agriculture, driving a shift toward smallholder farming systems. Historically, agricultural technologies have primarily catered to large, mechanized farms, exacerbating the disparity between large and small landholders. While strides have been made in achieving food security, livelihood security for farmers remains elusive, especially for smallholders and marginal farmers, who constitute over 80% of the global farming population. In India, these farmers account for nearly one-fourth of the world's small and marginal farms, cultivating less than 2 ha of land. Raising the income of these smallholders poses a significant challenge to researchers, policymakers, and governments. Given the constancy of land resources, horizontal intensification is not possible. The solution lies in vertical intensification through diversification, exemplified by the Integrated Farming System (IFS). IFS integrates various farming enterprises, allowing the by-products of one enterprise to serve as inputs for another, enabling resource recycling, efficient use of labour and space, and reduced market dependency. However, implementing on-station IFS models directly at farmers' fields is impractical due to high initial costs. Interventions targeting critical inputs within existing farming systems, as demonstrated by the All India Coordinated Research Project on Integrated Farming Systems–On-Farm Research (AICRP-Integrated-IFS-OFR), offer a promising alternative. By investing just ₹7,889 this approach achieved an 86% increase in net income within two years of implementation (2022–24), showcasing its potential to improve the livelihoods of small and marginal farmers effectively.

Keywords: Critical input, Integrated farming system, Livelihood security, Small and marginal farmers

The breakdown of joint families and population growth has led to fragmented landholdings (Rana 2015, Singh *et al*. 2017). Globally, there are approximately 570 million farms, of which 74% are located in Asia. China and India together account for 59% of the world's farms, with China holding 35% and India 24% (Lowder *et al*. 2016). A significant proportion of these farms are small, with over 410 million farms worldwide measuring less than 1 hectare, and more than 475 million farms measuring less than 2 hectares, comprising 72% and 84% of global farms, respectively. These small farms operate on just 12% of the global farmland, while the remaining 16% of farms, which are larger than 2 hectares, account for 88% of the farmland (Lowder *et al*. 2016). This disparity highlights the unequal distribution of land resources among farmers worldwide. In India, the 11th Agricultural Census (2020–21) showed the average holding size declined to 1.08 hectares from 2.28 hectares in 1970–71. Small and marginal holdings (below 2 ha) now make up 85% of total holdings but operate only 44.58% of the area, emphasizing challenges for smallholders (Dixon *et al*. 2001, Little and Edwards 2003). Most agricultural policies favour large-scale farmers, disadvantaging smallholders, who are critical to food security. Integrated Farming Systems (IFS) offer a sustainable solution by optimizing resources and diversifying operations. However, high implementation costs make directly replicating IFS models impractical. The Indian Institute of Farming Systems Research (IIFSR), through its scheme AICRP-IFS-OFR, has shown that strategic, region-specific interventions can enhance smallholders' livelihoods. This paper highlights the results achieved through the AICRP-IFS-OFR and explores how different central and state agencies can implement IFS at the field level. By focusing on limited but strategic interventions tailored to various modules and regional conditions, the study demonstrates the potential for scalable solutions to improve the productivity and profitability of small farms across diverse agro-climatic zones.

MATERIALS AND METHODS

Integrated Farming Systems (IFS) with location-specific, module-based, low-cost interventions were undertaken as part of the on-farm research component of the All India

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Coordinated Research Project on Integrated Farming Systems-On-Farm Research (AICRP-IFS-OFR). These interventions involved farmer-participatory refinement of IFS practices across five key modules to enhance food security, nutrition, environmental sustainability, and income for small and marginal farmers.

The five modules include, Bench mark (M_0); Cropping system/Diversification/Improvement (M_1); Livestock diversification/Improvement (M_2); Product diversification (M_3); Capacity building (M_4) (Table 1). These interventions, implemented in a participatory manner from 2022–23, aimed to double farm incomes while promoting food and nutrition security, environmental health, and eco-friendly agriculture. Two blocks were selected from each OFR centre (district), among these, one is high productive block and the other is low productive block. Block was selected based on the average district productivity, if block productivity is below the district productivity, then, it is considered low and if above the district productivity, then, it is considered high productive block. From each block, three villages were selected and in each village, six farmers were covered on a random basis. So, in total 36 farmers were covered in each centre. Total 23 district were covered from 14 agro-climatic zones, So, in total 828 farmers were covered across the country.

RESULTS AND DISCUSSION

Existing farming system characterization: Across the country, a total of 25 types of farming systems were recorded based on the permutation and combination of different farming components. It was observed that two-component farming systems are followed by 50% of households, three-component systems by 34% of farmers, four-component systems by 10% and five-component systems by 5%. Interestingly, about 1% of farmers incorporate six components into their systems. In terms of mean holding size and net return, there appears to be no direct relationship with the number of components followed. Among the various farming components, crops are the foundational element and occur in nearly all farming systems. Dairy emerges as the second most critical component, featuring in 83% of farming systems. Seven major farming systems were identified, with the following prevalence, Crop + Dairy with 42% in leading position; Crop + Dairy + Horticulture (11%); Crop + Dairy + Goatery (7%); Crop + Dairy + Goatery + Poultry (5%); Crop + Goatery (4.3%); Crop + Dairy + Goatery + Poultry (4.1%); and Crop + Dairy + Vegetable (2.8%). Together, these seven major farming systems represent 76% of the farming systems existing at the field level in the country.

The Crop + Dairy system generates a net income of ₹1.35 lakh from an average landholding of 0.96 ha. When, horticulture and vegetable components are integrated with the Crop + Dairy system, they provide additional returns. The highest net income per household and per unit of landholding was recorded in the Crop + Dairy + Horticulture system i.e. ₹1.78 lakh, followed closely by the Crop + Dairy + Vegetable system ₹1.44 lakh (Fig. 1). Conversely, the inclusion of goatery and poultry components tended to reduce net returns. This could be attributed to differences in resource availability between irrigated and rainfed areas. In irrigated areas, resource-rich farmers prefer high-value components, whereas, in rainfed areas, farmers often opt for goatry due to its lower water requirements. Backyard poultry is typically avoided by resource-rich farmers due to social obligations, while goatery faces challenges such as high mortality rates due to diseases, disorganized selling practices, lack of dry fodder throughout the year, and shrinking grazing lands. These factors collectively contribute to lower returns from goatry (Leith 2016).

Improvement in existing farming systems: Across the country, a total of 73 farming systems were refined through farmer-participatory approaches. These refinements were achieved by intervening in critical inputs, with an average cost of ₹7,889 spent on these inputs per system. There was considerable variation in net returns across locations, ranging from ₹4,786 at Mandla (Madhya Pradesh) to ₹1,87,994 at Alappuzha (Kerala). This intervention resulted in an increase in average net returns to ₹55,573 per system, representing an 86% increase in average net returns within the second year of intervention (Table 2 and Fig. 2). This significant improvement was attributed to module-based interventions targeting critical inputs that were scientifically derived from

Table 1 Module-wise intervention for improvement in existing farming systems

Farming System	Notation	Module name	Details
Existing	M_0	Bench mark	Recording of benchmark data on crops, livestock, other components, and household as a whole
Improved	M_1	Cropping system Diversification/ improvement	Most efficient cropping systems were introduced keeping in view the farmers' resources, perception, willingness, market, and requirement of other components in the system besides improving the practices of existing systems
	M_2	Livestock diversification/ improvement	Mineral mixture + deworming + round year fodder production + introduction of location-specific low-cost livestock components, viz. Backyard poultry, duckery, piggery and goat
	M_3	Product diversification	Preparation of mineral mixture/value addition of market surplus products/ kitchen/roof gardens
	M_4	Capacity building	Training of farm households on farming systems especially on newly added practices and components and assessing its impact

Table 2 Agro-climatic zone-wise farming system with the mean area and benchmark net income

ACR (Planning commission)	Name of centre	Number of farming systems	Number of farmer	Farming system description	Mean area (ha)	Benchmark net income (₹)
Western Himalayan Region	Udhampur (J&K)	3	24	Field crops + Dairy	0.49	60291
			6	Crop + Dairy + Goat	0.4	96974
			6	Crop + Dairy + Poultry	0.37	62475
	Kullu (HP)	3	18	Crop + Dairy	0.16	81825
			14	Crop + Dairy + Horticulture	0.2	60125
			6	Crop + Dairy + Goat/Sheep + Horticulture	0.16	17600
	Almora (UK)	2	7	Crop + Vegetables + Cattle + Goat	1.09	84905
			29	Crop + Vegetables + Cattle + Goat + Poultry	0.82	120281
Eastern Himlayan Region	Golaghat (Assam)	4	9	Crop + Dairy + Goatery + Poultry	1.35	91000
			9	Crop + Dairy + Goatery + Piggery + Poultry	1.39	95857
			11	Crop+Dairy+Goatery+Piggery+Poultry+Fishery	1.29	91250
			7	Crop + Dairy + Poultry + Fishery	1.26	76667
Lower Gangetic Plain	Bankura (WB)	4	18	Crop + Dairy + Goatery	0.9	19022
			5	Crop + Dairy + Poultry	0.81	19022
			7	Crop + Goatery + Poultry	0.55	19022
			6	Crop + Dairy + Goatery + Fishery	0.98	19022
Middle Gangetic Plain	Saharsa (Bihar)	4	6	Crop + Vegetables	0.79	107218
			18	Crop + Livestock	0.75	154204
			8	Crop + Livestock + Vegetables	0.83	173029
			4	Crop + Fisheries	1.08	133477
	Mau (UP)	1	36	Crop + Dairy	0.52	60279
Upper Gangetic Plain	Unnao (UP)	5	17	Crop + Dairy + Horticulture	0.757	104796
			8	Crop + Dairy + Horticulture + Goatery	0.469	68885
			8	Crop + Dairy	0.875	59269
			2	Crop + Horticulture	0.688	95035
			1	Crop + Dairy + Goatery	0.375	47925
	Modipuram (UP)	2	22	Crop + Dairy	1.62	201805
			14	Crop + Dairy + Horticulture	1.97	242800
Trans gangetic Plain	Rewari (Haryana)	1	36	Crop + Dairy (Buffalo/cow)	0.99	238148
Eastern Plateau and Hills	Saraikela-Kharsawan (Jharkhan)	2	18	Crop + Goat	1.2	34951
			18	Crop + Goat + Poultry	1.24	37420
	Mandla (MP)	5	15	Crop + Dairy	1.11	123071
			6	Crop + Dairy + Vegetable	0.97	170980
			4	Crop + Dairy + Poultry	0.86	124460
			5	Crop + Dairy + Goatery	1	118190
			6	Crop + Goatery + Poultry	1.28	130518
Central Plateau and Hills	Jabalpur (MP)	4	19	Crop + Dairy	1.02	114038
			8	Crop + Dairy + Vegetable	0.94	95811
			9	Crop + Dairy + Poultry	1.04	68667
			4	Crop + Dairy + Goatery	1.05	85311

Contnd.

Table 2 (*Concluded*)

ACR (Planning commission)	Name of centre	Number of farming systems	Number of farmer	Farming system description	Mean area (ha)	Benchmark net income (₹)
Western Plateau and Hills	Solapur	4	9	Crop + Dairy + Goatery + Poultry	0.87	134798
			13	Crop + Dairy + Goatery	0.81	118067
			6	Crop + Dairy + Poultry	0.81	118550
			8	Crop + Dairy	0.8	113920
	Nanded (MH)	4	10	Crop + Dairy	0.81	78236
			14	Crop + Goat	0.89	75481
			4	Crop + Horticulture	0.82	59370
			8	Crop + Sericulture	0.98	72984
	Wardha (MH)	2	15	Crop + Horticulture + Dairy	1.1	188133
			21	Crop + Dairy	0.96	117108
Southern Plateau and Hills	Dindigul (TN)	2	19	Crop + Dairy + Poultry	0.74	68934
			17	Crop + Dairy + Goat/Sheep + Poultry	0.91	60594
	Rangareddy (Telangan)	6	14	Crop + Dairy	0.93	75581
			7	Crop + Dairy + Sheep	0.94	99530
			8	Crop + Dairy + Poultry	0.84	69223
			3	Crop + Goatery	0.65	63925
			2	Crop + Dairy + Sheep + Vegetables	1.3	84750
			2	Crop + Dairy + Poultry + Vegetable	0.8	70088
East coast plains and hills	Khordha (Odisha)	5	18	Crop + Dairy	2.9	1,26,488
			5	Crop + Poultry	0.9	25,160
			5	Crop + Dairy + Poultry	1.2	1,52,680
			2	Crop + Goatery + Poultry	0.8	1,06,425
			6	Crop + Dairy + Poultry + Goatery	2.3	1,56,540
West Coast Plains and Hills	Uttara Kannada (KA)	2	16	Crop + Dairy	0.88	281375
			20	Crop + Dairy + Horticulture	0.77	320690
	Alappuzha (Kerala)	4	9	Coconut based IFS	0.66	102334
			9	Rice based IFS	1.03	68484
			9	Dairy-based FS	0.61	223651
			9	Aquaculture-based FS	0.62	186514
Western dry region	Rajasmand (RJ)	3	14	Crop + Dairy	0.77	72068
			8	Crop + Dairy + Horticulture	0.87	59697
			14	Crop + Dairy + Poultry	0.79	78445
Gujarat Plains and Hills	Sabarkantha (GJ)	1	36	Crop + Dairy	0.2	73064

on-station research results. These findings highlighted the potential of module-based interventions in IFS to double farm incomes within two years when implemented in a participatory mode. Different studies showed that IFS have the potential to increase the overall productivity of farms (Panwar *et al*. 2021, Paramesh *et al*. 2022, Raghavendra *et al*. 2024).

Promising interventions based on agro-climatic zones (ACZs): Drawing from the experiences of the AICRP-IFS-OFR and other studies, various ACZ-specific

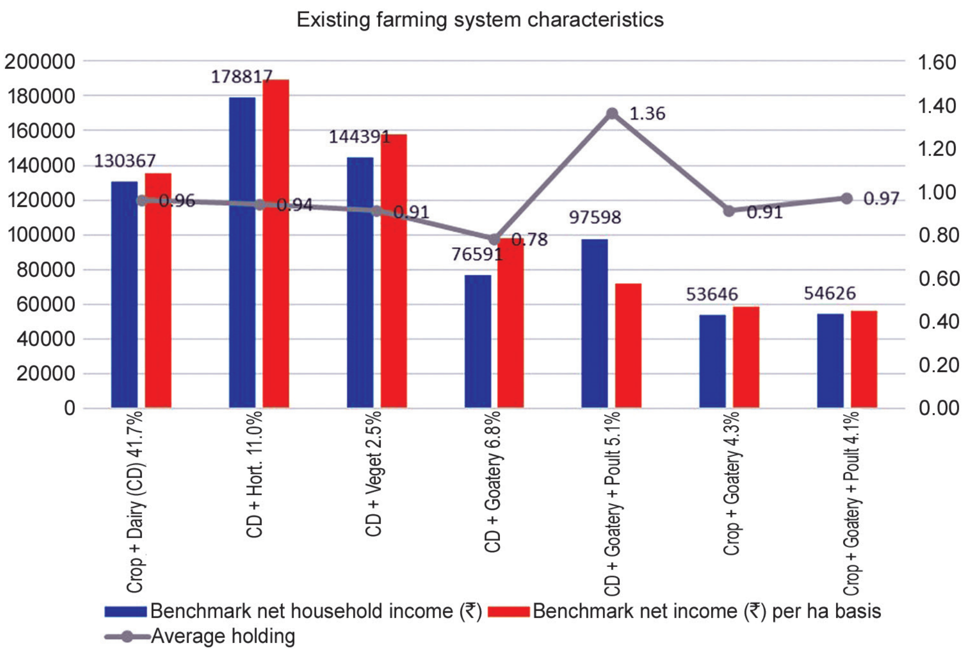

Fig. 1 Existing major farming systems across the country have mean holding size and benchmark net household income along with benchmark net income/ha basis.

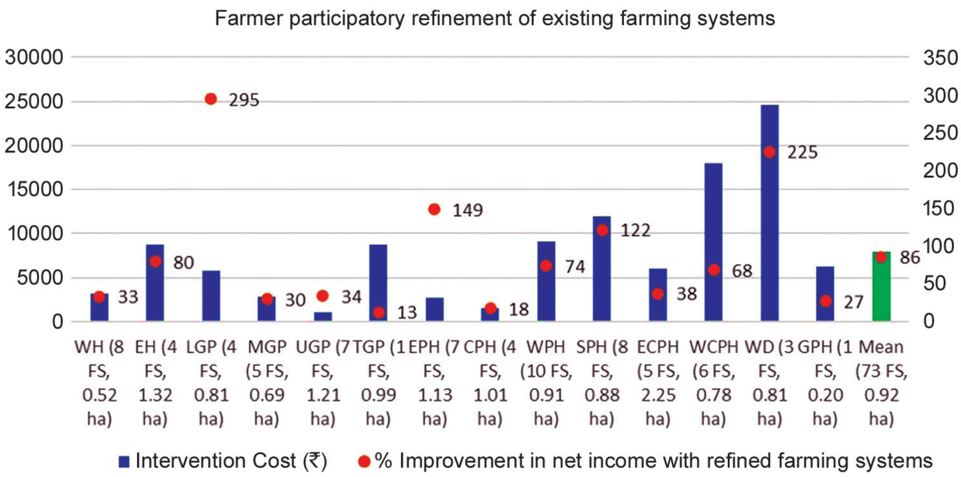

Fig. 2 ACZ wise percent increase in net return along with intervention cost (Refer to Table 3 Abbreviations).

interventions can be recommended (Supplementary Table 1). These interventions aim to optimize resource use and enhance farmers' livelihoods through integrated approaches. Different extension agencies can implement these interventions effectively at the field level (Table 3).

Promising interventions at farmers' fields in western Uttar Pradesh

Late sown wheat varieties (DBW-173, HD-3298, HD-3271): Suitable for late sowing after sugarcane harvest and is less affected by terminal heat stress.

Gobhi Sarson (GSC-7) intercropped with sugarcane: Serves as a winter fodder alternative to sugarcane tops, ensuring sustainable livestock feeding practices.

Bajra Napier Hybrid (BNH Co-5): A perennial fodder crop providing round-the-year fodder availability for livestock, contributing to enhanced animal productivity.

Mustard (RH-725) cultivation: Integrated into sugarcane ratoon cropping systems to ensure timely sowing of sugarcane and improved crop rotation benefits.

Animal rubber mat usage: Ensures animal comfort, leading to increased productivity by reducing stress and enhancing overall welfare.

Pest and disease-resistant sugarcane varieties (Co-0118, Co-15235, Co-14201, Co-98014): Minimize damage as large area under single variety Co-0238.

Policy implications: The government should prioritize designing schemes that provide improved critical inputs in a scientific manner, which can significantly boost farmers' income nationwide. Instead of providing blanket subsidies, a portion of the PM Kisan Samman Nidhi could be allocated to incentivize farmers to invest in critical inputs. This approach ensures the money is spent on impactful interventions that enhance farm productivity and sustainability. Such scientifically designed, need-based interventions have the potential to transform Indian agriculture, improving both income levels and the overall livelihood of farming communities.

The study clearly indicates that module-wise, targeted interventions on critical inputs in IFS, implemented in a farmers' participatory mode, have the potential to double farmers' incomes within the second year of intervention. Even a relatively small investment in critical inputs can yield substantial improvements in net returns. Replicating on-station IFS models directly at farmers' fields is challenging due to local variations and constraints. Therefore, module-wise interventions tailored to address specific constraints are essential for maximizing impact. To achieve a country-wide transformation, the government should reconsider its policies and promote schemes that encourage farmers to allocate resources toward critical inputs. This can be facilitated by redirecting funds from existing schemes or reallocating a

Table 3 Agroclimatic zone wise refine farming system with intervention cost and improvement in net income

Agroclimatic zone	OFR centre	Number of farming systems refined	Mean area (ha)	Intervention cost (₹)	Improvement in net income over benchmark	Percent improvement in net income over benchmark
Western Himalayan (WH)	Udhampur	3	0.42	6029	42721	56.3
	Kullu	3	0.17	639	11203	36.0
	Almora	2	0.96	2871	7786	7.9
	Total	8	0.52	3180	20570	33.4
Eastern Himlayan (EH)	Golaghat	4	1.32	8770	70620	79.8
	Total	4	1.32	8770	70620	79.8
Lower Gangetic Plain (LGP)	Bankura	4	0.81	5838	56046	294.6
	Total	4	0.81	5838	56046	294.6
Middle Gangetic Plain (MGP)	Saharsa	4	0.86	1800	8519	6.0
	Mau	1	0.52	3798	32406	53.8
	Total	5	0.69	2799	20462	29.9
Upper Gangetic Plain (UGP)	Unnao	5	0.63	1096	24459	33.9
	Total	5	1.21	1096	24459	33.9
Transgangetic Plain (TGP)	Rewari	1	0.99	8766	30552	12.8
	Total	1	0.99	8766	30552	12.8
Eastern Plateau and Hills (EPH)	Saraikela-Kharsawan	2	1.22	4045	103896	293.9
	Mandla	5	1.04	1500	4786	3.9
	Total	7	1.13	2773	54341	148.9
Central Plateau and Hills (CPH)	Jabalpur	4	1.01	1525	15399	18.0
	Bharatpur				0	
	Total	4	1.01	1525	15399	18.0
Western Plateau and Hills (WPH)	Solapur	4	0.82	970	14557	11.9
	Nanded	4	0.88	10818	85780	118.2
	Wardha	2	1.03	15366	133089	92.0
	Total	10	0.91	9051	77808	74.1
Southern Plateau and Hills (SPH)	Dindigul	2	0.83	11351	84116	132.6
	Rangareddy	6	0.93	12420	86094	110.5
	Total	8	0.88	11885	85105	121.6
East coast plains and hills (ECPH)	Khordha	5	2.25	6000	36985	37.5
	Total	5	2.25	6000	36985	37.5
West Coast Plains and Hills (WCPH)	Uttara Kannada	2	0.83	6700	40754	13.5
	Alappuzha	4	0.73	29268	187994	123.3
	Total	6	0.78	17984	111060	68.4
Western Dry region (WD)	Rajasmand	3	0.81	24569	154787	225.2
	Total	3	0.81	24569	154787	225.2
Gujarat Plains and Hills (GPH)	Sabarkantha	1	0.20	6217	19833	27.1
	Total	1	0.20	6217	19833	27.1
	Grand Total	71	0.92	7889	55573	86.1

Fig. 3 Promising interventions at farmer's field in Western Uttar Pradesh. (A) Sugarcane + *Gobhi sarso* GSC-7; (B) Bajra Napier Hybrid (BNH Co-5); (C) Mustard RH-725; (D) Animal rubber mat.

portion of the PM Kisan Samman Nidhi toward scientifically designed interventions. Such an approach would enhance the reach and impact of the IFS participatory model, driving sustainable growth and improving the livelihoods of farmers across the nation.

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