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Integrated Crop-Livestock Systems and Household Income Enhancement: Evidence from Telangana Farmers

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Abstract:
Integrated crop–livestock systems (ICLS) are promoted as a pathway to raise the incomes of small and marginal farmers in rainfed regions, yet evidence from Telangana remains thin. This study compares 120 ICLS-adopting and 120 non-adopting farm households in three erstwhile districts (Mahabubnagar, Nalgonda and Warangal) using primary data for the agricultural year 2018–19. Income, its composition, enterprise returns and resource-use indicators were analysed through descriptive statistics, ordinary least squares regression, propensity-score matching and Garrett's ranking technique. ICLS households earned ₹1,57,000 annually, 25.1 per cent more than the ₹1,25,500 earned by non-adopters. Livestock supplied 33.7 per cent of adopters' income against 10.9 per cent for non-adopters, while dependence on agricultural wage labour fell from 23.0 to 9.0 per cent. After controlling for farm size, education, irrigation, credit and extension, adoption raised income by about 20.6 per cent, and matching estimates confirmed a gain of ₹28,900. Proportional gains were largest among marginal farmers. Adopters also generated 21.9 per cent more employment and spent 23.8 per cent less on fertiliser per hectare. Summer fodder scarcity, costly feed, and weak veterinary services were the main constraints. The study recommends fodder banks, stronger animal-health services, livestock credit and cooperative marketing to scale ICLS in Telangana.

Keywords: integrated crop–livestock systems; household income; farm diversification; small and marginal farmers; Telangana; propensity-score matching.

1. Introduction

Agriculture in Telangana combines small holdings with large risk. About 86 per cent of cultivators operate marginal or small holdings; the average holding is only 1.12 hectares, and nearly three-quarters of cultivating households are in debt (Reddy, 2020). Groundwater supplies roughly 82 per cent of the net irrigated area, so a failed monsoon or a falling water table quickly becomes a failed crop (Reddy, 2020). Average agricultural household income was estimated at ₹75,732 a year, far below the roughly ₹2,25,000 that a five-member household needs from net income to cross the international poverty line (Reddy, 2020).

India's goal of doubling farmers' real income by 2022–23 has drawn attention to sources of growth beyond field crops (Chand, 2017; Dalwai, 2018). Livestock is the most obvious candidate. In Telangana, the livestock sector contributed 5.9 per cent of gross state domestic product (GSDP) in 2015–16, equal

to the crop sector (Reddy, 2020), and by 2019–20 its share of 6.85 per cent had edged ahead of crops at 6.25 per cent (Comptroller and Auditor General of India [CAG], 2021). The 2019 Livestock Census recorded 3.26 crore animals in the state, more than half of them sheep (Department of Animal Husbandry and Dairying [DAHD], 2019).

Integrated crop–livestock systems (ICLS): intentional connection between the two sectors within the same farm. Crop residues and fodder are given to animals, dung and urine are returned to the soil, and animals provide milk, meat, draught power, and a liquid asset which can be sold in a bad year (Gupta et al., 2012; Herrero et al., 2010). The added value of ICLS is that the output of one enterprise becomes the input of another, thus reducing the risk of purchased inputs, distributing income over the year, and reducing weather and price risk (Behera & France, 2016; Lemaire et al., 2014). Other research in India has found integration to be possible even on holdings as small as 1.5 acres (Ramrao et al., 2006) and livestock to be a means for making agriculture more inclusive (Birthal & Negi, 2012).

Such gains have not been researched at the household level in the context of the semi-arid climate in Telangana, its declining groundwater resources, and increasing demand for meat and milk. The literature on the state uses primarily statistical abstracts and national survey data (Reddy 2020) and provides little insight into its impact on the true value of the farm income that is earned, who earns it, and how it is done.

This paper fills this void. Its objectives are:

1. To explain the socio-economic characteristics of ICLS adopting and non-adopting farm families;
2. To record the ICLS models being adopted and the results of livestock businesses;
3. To compare the amount and type of income received by the household in the two groups;
4. to assess the impact of the adoption of ICLS on household income after adjusting for other factors; and
5. to measure the differences in the use of resources and employment; and
6. To determine constraints for uptake.

The analysis is based on three hypotheses. H1: Household income increases with the adoption of ICLS. Adopting ICLS increases the proportion of livestock income and decreases reliance on farming wage labour. H3: The proportional increase in income is greater among marginal and small farmers compared to larger farmers.

The rest of the paper examines the relevant literature, outlines a conceptual framework, outlines the data and the method, presents and discusses the results, and draws policy conclusions.

2. Review of Literature

2.1 Rationale for integration

Mixed crop–livestock systems in much of the developing world are the pillars of food production and Herrero et al. (2010) recommended that sustainable intensification of these systems should be prioritized for investment. Russelle et al. (2007) and Wilkins (2008) presented a similar argument for the industrialised world by claiming more efficient use of resources and better nutrient cycling results from re-linking crop and animal production. Lemaire, et al. (2014) explained integration as a method to construct synergy between production and environmental quality. In Australia, Bell and Moore (2012) concluded that mixed farming is mainly a risk management policy, which is also the case in rainfed

Telangana with variable yields and prices.Garrett et al. (2017), however, concluded that the evidence on social and economic outcomes of integrated systems is thinner than the agronomic evidence, which is the gap that household-level studies can help close.

2.2 Evidence from India

In the Indian context, Behera and France (2016) reviewed integrated farming systems and concluded that they improve livelihood security, employment, and nutrient recycling for small and marginal farmers. Gupta et al. (2012) highlighted ICLS as a conservation and environmentally friendly strategy with emphasis on the utilization of crop residues and animal manure. Ramrao et al. (2006) found that the integration of multiple enterprises was economically sound and created approximately 316 days of employment on a 1.5-acre, rainfed plot of land in Chhattisgarh. Srinivasa Rao et al. (2015) found that the integration of livestock was one of the major strategies to mitigate variability in rainfall conditions for rainfed farms.

2.3 Farm size, livestock and income

Small farms' income crisis is a well-documented issue. Chand et al. (2011) demonstrated that although the smallholder could be very productive on a small piece of land, he/she still has low income due to the small size of the land, so livelihoods are not only based on the main crop. Dev (2012) concluded the same and highlighted livestock and allied activities as an opportunity for small farmers. Birthal et al. (2014) analysed income sources of Indian farm households and showed that livestock and non-farm income are distributed more equally than crop income. Birthal et al. (2015) found that diversification can reduce farm poverty, with small farms among the beneficiaries. Birthal and Negi (2012) argued that livestock can drive growth that is higher, more sustainable and more inclusive than crop-led growth, because it is labour-intensive and spread across many poor households. Thornton (2010) noted that rising demand for animal-source food makes livestock an expanding source of livelihood for the poor.

For Telangana specifically, Reddy (2020) showed that during the drought years of 2014–15 and 2015–16 the crop sector's contribution fell sharply while that of livestock and fisheries held steady or rose. He therefore advised that livestock farming be encouraged to cushion bad monsoons and to create employment for small and marginal farmers. National household data point in the same direction: the Situation Assessment Survey recorded that income from animal rearing was a small share of agricultural household income, with large scope for expansion (National Sample Survey Office [NSSO], 2014).

2.4 Research gap

Three gaps emerge. First, household-level evidence on ICLS in Telangana is scarce; most state-level analyses use aggregates. Second, many Indian studies are single-site or demonstration-farm assessments without a comparison group, so they cannot separate the effect of integration from the characteristics of the farmers who choose it. Third, few studies examine, together, income level, income composition, resource use, and adoption constraints. This paper addresses all three by comparing adopters with non-adopters, controlling for observable differences through regression and matching, and examining the mechanisms behind any income gain.

3. Conceptual Framework

The analysis rests on the sustainable livelihoods perspective, in which households convert assets and institutional support into livelihood strategies and outcomes (Ellis, 2000; Scoones, 1998). Figure 1 applies that logic to ICLS. Three groups of conditions shape what a household can do: its resources (land, irrigation and family labour), institutional support (credit, extension, markets and veterinary care) and the farmer's own attributes (age, education, experience and group membership).

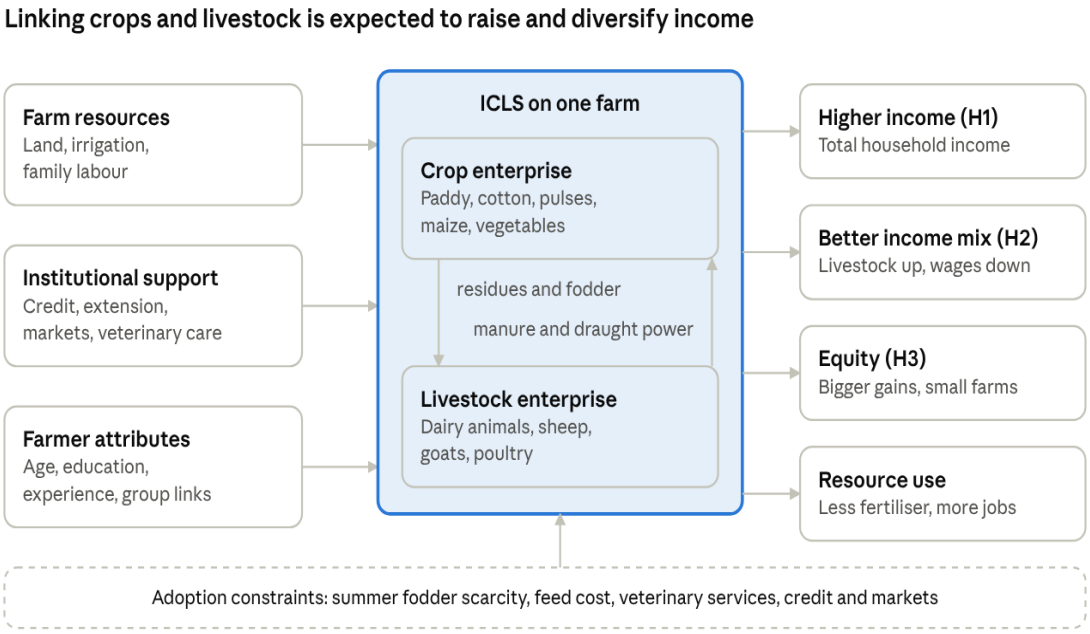


Figure 1. Conceptual framework: ICLS linkages and expected outcomes (author's framework)

Inside the farm, ICLS creates two-way flows. Crop residues and cultivated fodder feed the animals, which lowers feed purchases; animals return manure, which substitutes for part of the chemical fertiliser, and supply draught power. They also generate milk, meat, eggs and live-animal sales through the year, unlike the lumpy harvest income of crops. Three outcomes follow from this logic and correspond to the hypotheses stated in the Introduction. Total income rises (H1); the income mix shifts towards livestock and away from wage labour (H2); and gains are proportionally larger on small farms (H3), because small farms are labour-abundant relative to land (Chand et al., 2011) and need little additional fixed capital to keep a few milch animals or small ruminants. Constraints on feed, animal health, credit and markets decide whether households can adopt and how far, which is why they are analysed separately.

4. Research Methodology

4.1 Study area

The study was conducted in three erstwhile districts of Telangana: Mahabubnagar, Nalgonda and Warangal. They were selected purposively to represent contrasting farming environments. Mahabubnagar is a drought-prone rainfed district where sheep and goat rearing is a traditional livelihood. Nalgonda and Warangal combine groundwater-irrigated paddy with cotton, and both have

seen rapid expansion of cotton area in recent years (Reddy, 2020). Together, they cover the range of rainfed to semi-irrigated conditions in which ICLS is practised in the state.

4.2 Sampling design

A multistage sampling design was followed. Two mandals were chosen in each district, with two villages in each mandal, giving 12 villages. Households in each village were listed and screened for ICLS status. An ICLS-adopting household was defined as one that cultivated crops, kept at least 2.0 tropical livestock units (TLU; Jahnke, 1982), and practised at least two crop–livestock linkages: feeding own crop residues or cultivated fodder to animals, returning dung to its own fields, or using its own animals for draught. A non-adopting household was a crop-based household with fewer than 1.5 TLU and no more than one such linkage. Ten adopters and ten non-adopters were drawn from each village by simple random sampling, giving 120 households in each group and 240 in all. For a proportion estimated at the full-sample level, this size gives a margin of error of about 6.3 percentage points at the 95 per cent confidence level (Cochran, 1977).

4.3 Data and income concepts

Primary data were collected through personal interviews with a pre-tested, structured schedule between October 2019 and January 2020, after a pilot in 12 households outside the sample. Agricultural year 2018-19 (July 18 to June 19) was the reference period. Information included household characteristics, land use and irrigation, livestock holdings, inputs used, outputs and sales, labour use, sources of income, and ranking of constraints. Secondary data on the state economy and stock of livestock have been collected from Socio-Economic Outlook 2020 (Government of Telangana, 2020), 20th Livestock Census (DAHD, 2019), and State Finances Audit Report (CAG, 2021).

The gross value of output from each source was measured as net income, defined as gross value of output minus paid-out costs and depreciation (Kothari, 2004). Family labour was not imputed as a cost, so the figures represent the return to the household from each activity. Farm-gate value was used when calculating the value of fodder and manure produced on the farm. Total household income is the sum of net income from crops, livestock, agricultural wage labour and non-farm sources, expressed in current rupees of 2018–19. Farm-size classes follow the standard Agriculture Census categories: marginal (below 1 ha), small (1–2 ha), semi-medium (2–4 ha) and medium (4–10 ha).

4.4 Analytical tools

Profile and income variables were compared using Welch's t-test for continuous variables and the chi-square test for proportions. The effect of adoption on income was estimated with an ordinary least squares (OLS) regression of the log of total household income, with heteroskedasticity-robust standard errors (Gujarati & Porter, 2009):

$$InY_i = \beta_0 + \beta_1 ICLS_i + \sum_{k=2}^{10} \beta_k X_{ki} + \in_i$$

where Y is total household income, ICLS is a dummy equal to one for adopters, and X are age, education, family size, the log of operational holding, share of irrigated area, access to credit, extension contact and district dummies. Because adoption is not randomly assigned, the OLS estimate was checked with propensity-score matching: the probability of adoption was estimated by logit on the same

covariates, and each adopter was matched to the nearest non-adopter within a caliper of 0.05 to obtain the average treatment effect on the treated (ATT; Rosenbaum & Rubin, 1983). Constraints were ranked by respondents and analysed with Garrett's ranking technique (Garrett & Woodworth, 1969), in which each rank is converted to a percent position:

$$Percent\ position = \frac{100(R_{ij} - 0.5)}{N_j}$$

with R as the rank given to the i-th constraint by the j-th respondent and N as the number of constraints ranked by that respondent. Positions are converted to scores from Garrett's table and averaged across respondents.

5. Results and Discussion

5.1 Socio-economic profile

Table 1 profiles the sample. Adopters and non-adopters were statistically similar in age, education, family size, operational holding, irrigated share and farm-size distribution, which supports their comparability. The average holding of about 2 hectares is larger than the state average of 1.12 hectares (Reddy, 2020) because the sample covers actively farming households in three districts rather than all rural households. The groups differed in access to supporting institutions. Institutional credit reached 71.7 per cent of adopters against 58.3 per cent of non-adopters, extension contact 64.2 against 45.0 per cent, and membership of a self-help group, producer organisation or dairy cooperative 47.5 against 28.3 per cent. These differences are why credit, extension and farm characteristics are controlled in the regression and matching analysis. By construction, adopters kept far more livestock (3.2 TLU against 0.8 TLU).

Table 1. Socio-economic profile of sample households (n = 240)

Characteristic	ICLS adopters (n = 120)	Non-adopters (n = 120)	Test statistic
Age (years)	46.8	45.2	t = 1.28
Education (years of schooling)	6.9	6.1	t = 1.61
Family size (persons)	4.8	4.6	t = 1.07
Operational holding (ha)	2.13	1.99	t = 0.89
Irrigated share of holding (%)	38.4	35.9	t = 0.79
Farm size: marginal / small / semi-medium / medium (% of households)	18.3 / 34.2 / 35.0 / 12.5	24.2 / 33.3 / 31.7 / 10.8	χ^2 = 1.32
Access to institutional credit (% of households)	71.7	58.3	χ^2 = 4.69**
Extension contact (% of households)	64.2	45.0	χ^2 = 8.89***
Member of SHG, producer organisation or dairy cooperative (%)	47.5	28.3	χ^2 = 9.36***
Livestock holding (TLU per household)	3.2	0.8	t = 15.68***

Note. Source: field survey, 2019–20. Welch's t-test for continuous variables, chi-square for proportions. *** p < .01, ** p < .05; unmarked differences are not significant.

5.2 ICLS models and linkage practices

Table 2 shows the models practised. Crop–dairy was the most common (34.2 per cent), followed by crop–small ruminants (27.5 per cent). One in six (17.5 per cent) of homes had sheep or goats as well as dairy animals and one in five (20.8 per cent) had poultry in addition to crops. These linkages practices demonstrate the practice of integration. Almost all the adopters added dung or farmyard manure (92.5 per cent) to their fields, four in five feeding crop residues to animals (81.7 per cent) and 60.0 per cent growing green fodder. Biological connection by dung and residues was therefore predominant, pointing to a low intensity of integration and potential for increased intensity by residue use (Gupta et al., 2012).

Table 2. ICLS models and linkage practices among adopters (n = 120)

Category	Households	Per cent of adopters
ICLS model		
Crop + dairy (buffalo or cattle)	41	34.2
Crop + small ruminants (sheep or goats)	33	27.5
Crop + dairy + small ruminants	21	17.5
Crop + poultry	25	20.8
Linkage practice (multiple response)		
Dung or farmyard manure returned to fields	111	92.5
Crop residues fed to animals	98	81.7
Cultivated green fodder	72	60.0
Animals used for draught or transport	29	24.2
Compost pit or vermicompost	18	15.0

Note. Source: field survey, 2019–20.

5.3 Returns from livestock enterprises

Table 3 reports returns from the three livestock enterprises. Dairy gave the highest net return per participating household (₹60,000), but small ruminants had the best benefit–cost ratio (1.86), which reflects low housing and feed costs where animals graze crop residues and common land. Poultry earned the least (₹23,000) but needed the smallest capital outlay. Purchased feed and fodder was the largest cost item in all three enterprises, a point that returns in the analysis of constraints. Averaged over all 120 adopters, livestock added ₹52,892 of net income per household, which is shown as ₹52,900 in Table 4 after rounding.

Table 3. Annual returns from livestock enterprises, per household, 2018–19 (₹)

Enterprise	Households	Gross returns	Total cost	Net returns	Benefit–cost ratio
Dairy (buffalo or cattle)	62	1,48,000	88,000	60,000	1.68
Small ruminants (sheep or goats)	54	82,000	44,000	38,000	1.86
Poultry	25	61,000	38,000	23,000	1.61
All adopters (average per	120	1,26,075	73,183	52,892	1.72

Enterprise	Households	Gross returns	Total cost	Net returns	Benefit–cost ratio
household)					

Note. Source: field survey, 2019–20. Enterprise rows are per participating household; 21 households keep both dairy animals and small ruminants and appear in both rows. Costs include purchased and own-farm feed, veterinary care, hired labour, and depreciation.

5.4 Level and composition of household income

Table 4 and Figure 2 compare income. ICLS households earned ₹1,57,000 a year against ₹1,25,500 for non-adopters, a difference of ₹31,500 or 25.1 per cent ($t = 4.16$, $p < .01$), which supports H1. The composition explains the gap. Livestock added ₹39,200 more for adopters, more than the whole net difference, while income from agricultural wage labour was ₹14,700 lower. Adopters earned 12.7 per cent more from crops (₹7,900), but this difference was not statistically significant. Non-farm income was almost identical in the two groups.

The income mix changed accordingly, which supports H2. Livestock supplied 33.7 per cent of adopters' income but 10.9 per cent of non-adopters', and reliance on agricultural wage labour fell from 23.0 to 9.0 per cent. Even the non-adopter's livestock share is above the roughly 6 per cent (₹374 of ₹6,311 per month) that national survey data show for agricultural households in the state (Reddy, 2020), which suggests that sampled non-adopters keep some animals without integrating them. The shift away from wage work is consistent with household labour being redeployed to fodder, animal care and the farm itself rather than sold outside. The pattern agrees with Birthal et al. (2014), who found livestock income more equally distributed than crop income, and with Reddy (2020), who recommended livestock as a hedge against drought-prone cropping.

Table 4. Annual household income by source, 2018–19
(₹ per household; share of total in parentheses)

Source of income	ICLS adopters	Non-adopters	Difference	t-value
Crop cultivation	70,300 (44.8)	62,400 (49.7)	+7,900	1.55
Livestock	52,900 (33.7)	13,700 (10.9)	+39,200	9.87***
Agricultural wage labour	14,200 (9.0)	28,900 (23.0)	−14,700	−5.73***
Non-farm (business, salaried work, remittances)	19,600 (12.5)	20,500 (16.3)	−900	−0.42
Total household income	**1,57,000 (100.0)**	**1,25,500 (100.0)**	**+31,500**	**4.16***

Note. Source: field survey, 2019–20. Welch's t-test. *** $p < .01$. Non-adopter shares sum to 99.9 because of rounding.

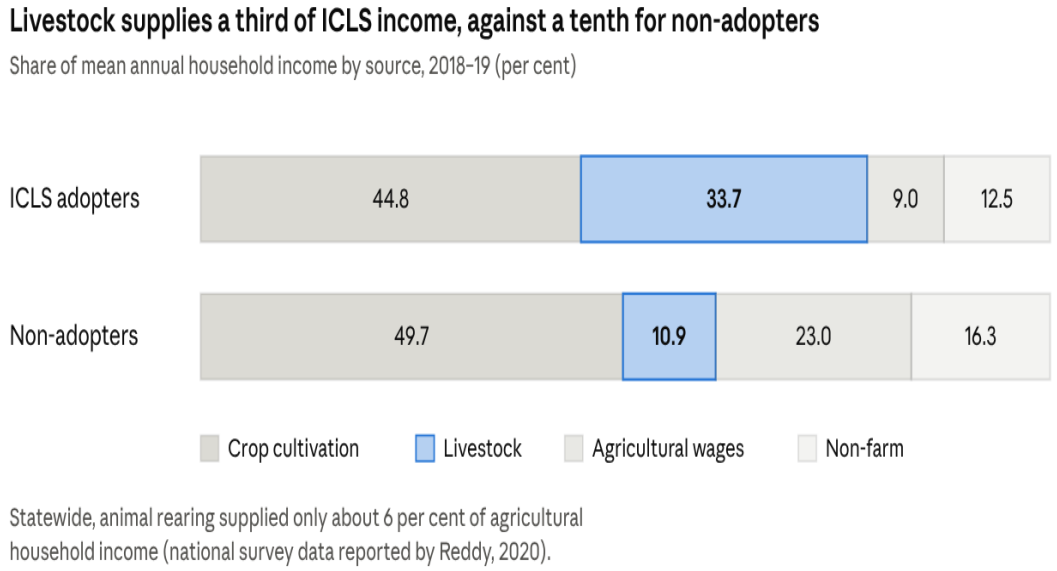


Figure 2. Composition of household income by source, ICLS adopters and non-adopters (field survey, 2019–20)

5.5 Income gains by farm size

Table 5 and Figure 3 test H3. In absolute terms, the income advantage of ICLS rose with farm size, from ₹24,000 for marginal farmers to ₹32,900 for medium farmers. Proportionally, however, marginal farmers gained most (30.0 per cent), followed by small farmers (22.2 per cent), while semi-medium and medium farmers gained about 18 to 19 per cent. The ICLS coefficient of 0.187 is positive and significant at the 1 per cent level: ceteris paribus, income is around 20.6 per cent higher for adopters than for the non-adopters, as compared to the raw difference of 25.1 per cent. The same was true in the propensity-score matching analysis. For 120 adopters, the standardised mean differences on all covariates were below 10 per cent after matching; the ATT was ₹28,900 per household (bootstrap SE ₹8,100), or 23.0 per cent of the non-adopter mean. Both methods give the same result, but both use a set of observed covariates and cannot rule out unobserved differences (such as farmer motivation) between the two, and so the estimates should be interpreted as associations rather than as causation.

Other outcomes are self-explanatory. Land matters, but less than proportionally: A 1 per cent increase in holding size increases income by 0.31 per cent, similar to Chand et al., (2011)'s argument on small farms productivity. Additional years of education increased income by 1.7 per cent, an additional percentage point of irrigated land by 0.28 per cent and access to credit by 9.9 per cent. Extension contact was good but not a strong one. The households in Mahabubnagar were earning approximately 11.1 per cent less than the households in Nalgonda, which reflects the drought prone environment of Nalgonda.

Marginal ICLS adopters still earned only ₹1,04,000 a year, and even medium adopters earned ₹2,08,600, below the roughly ₹2,25,000 that Reddy (2020) estimates a five-member household needs from net income to cross the international poverty line. ICLS narrows the income gap but is not by itself sufficient for the smallest farms.

Table 5. Mean annual household income by farm-size class, 2018–19 (₹)

Farm-size class	Adopters (n)	Non-adopters (n)	ICLS adopters	Non-adopters	Difference
Marginal (below 1 ha)	22	29	1,04,000	80,000	24,000
Small (1–2 ha)	41	40	1,43,000	1,17,000	26,000
Semi-medium (2–4 ha)	42	38	1,80,000	1,52,000	28,000
Medium (4–10 ha)	15	13	2,08,600	1,75,700	32,900
All households	**120**	**120**	**1,57,000**	**1,25,500**	**31,500**

Note. Source: field survey, 2019–20. Class means are weighted by sample size to give the all-household means.

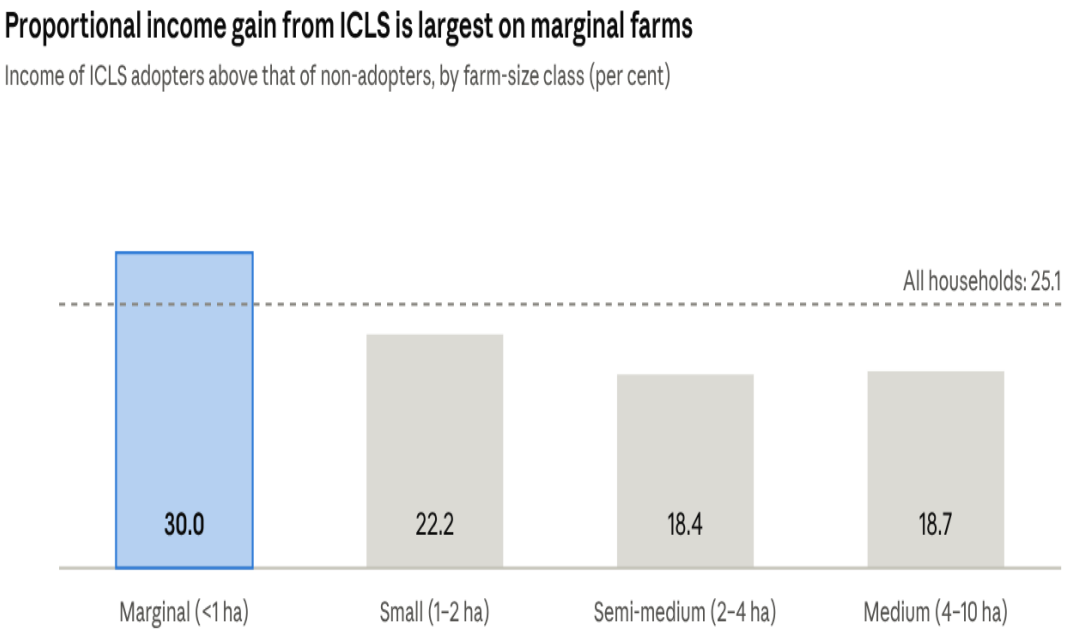


Figure 3. Percentage income gain from ICLS by farm-size class (field survey, 2019–20)

5.6 Resource use and employment

Table 6 shows how integration changed resource use. Adopters spent ₹2,130 less per hectare on chemical fertiliser (23.8 per cent lower) while applying 5.8 tonnes of farmyard manure per hectare against 1.9 tonnes. About 78 per cent of their crop residue was fed to animals, against 24 per cent for non-adopters. Net crop income per hectare was 5.3 per cent higher, and cropping intensity rose by 16 percentage points, partly through fodder crops grown in the rabi and summer seasons. These are the nutrient-recycling and cost-saving mechanisms that the conceptual framework predicted (Behera & France, 2016; Gupta et al., 2012). Adopters also generated 412 person-days of employment per household against 338, a rise of 21.9 per cent, in line with the employment gains Ramrao et al. (2006) reported for integrated systems. Combined with the lower wage income in Table 4, this suggests that integration absorbed family labour on the farm, an outcome of particular value in a state where agricultural labourers outnumber cultivators (Reddy, 2020).

Table 6. Resource use, crop returns and employment, 2018–19

Indicator	ICLS adopters	Non-adopters	Difference	Per cent difference
Chemical fertiliser expenditure (₹ per ha)	6,820	8,950	−2,130	−23.8
Farmyard manure applied (tonnes per ha)	5.8	1.9	+3.9	+205.3
Crop residue fed to animals (% of residue)	78	24	+54 points	–
Cropping intensity (%)	168	152	+16 points	–
Net crop income (₹ per ha)	33,005	31,357	+1,648	+5.3
Employment (person-days per household per year)	412	338	+74	+21.9

Note. Source: field survey, 2019–20. Net crop income per hectare is mean crop income divided by mean operational holding.

5.7 Determinants of household income

Table 7 presents the OLS regression of log household income. The model explains 47 per cent of the variation (adjusted $R^2 = 0.447$; $F = 20.31$, $p < .01$). The ICLS coefficient of 0.187 is positive and significant at the 1 per cent level: ceteris paribus, income is around 20.6 per cent higher for adopters than for the non-adopters, as compared to the raw difference of 25.1 per cent. The same was true in the propensity-score matching analysis. For 120 adopters, the standardised mean differences on all covariates were below 10 per cent after matching; the ATT was ₹28,900 per household (bootstrap SE ₹8,100), or 23.0 per cent of the non-adopter mean. Both methods give the same result, but both use a set of observed covariates and cannot rule out unobserved differences (such as farmer motivation) between the two, and so the estimates should be interpreted as associations rather than as causation.

Other outcomes are self-explanatory. Land matters, but less than proportionally: A 1 per cent increase in holding size increases income by 0.31 per cent, similar to Chand et al. (2011)'s argument on small farms' productivity. Additional years of education increased income by 1.7 per cent, an additional percentage point of irrigated land by 0.28 per cent, and access to credit by 9.9 per cent. Extension contact was good but not a strong one. The households in Mahabubnagar were earning approximately 11.1 per cent less than the households in Nalgonda, which reflects the drought-prone environment of Nalgonda.

Table 7. OLS regression of log of total household income (n = 240)

Variable	Coefficient	Robust SE	t-value
ICLS adoption (1 = adopter)	0.187***	0.049	3.82
Age (years)	−0.002	0.002	−1.00
Education (years of schooling)	0.017**	0.007	2.43
Family size (persons)	0.021	0.015	1.40
Log of operational holding (ha)	0.312***	0.046	6.78
Irrigated share of holding (%)	0.0028***	0.0010	2.80
Access to credit (1 = yes)	0.094**	0.046	2.04

Variable	Coefficient	Robust SE	t-value
Extension contact (1 = yes)	0.081*	0.044	1.84
Mahabubnagar (reference: Nalgonda)	−0.118**	0.052	−2.27
Warangal (reference: Nalgonda)	0.036	0.051	0.71
Constant	10.412***	0.190	54.80

Note. Source: field survey, 2019–20. $R^2 = 0.470$; adjusted $R^2 = 0.447$; $F(10, 229) = 20.31$. *** p < .01, ** p < .05, * p < .10.

5.8 Constraints to adoption

The constraints are ranked in Table 8. The scarcity of fodder in the summer months was the most common problem (Garrett score 68.4), followed by the high cost of concentrate feed (64.2) and inadequate veterinary and artificial insemination services (59.7). The top three relate to feed and animal health, not to markets, as purchased feed was the greatest cost in all three enterprises. Purchasing animals, low prices for milk and meat, disease losses, a shortage of labour, and water and grazing lands came after. The ranking points to bottlenecks in the supply side that can be solved by policy measures such as fodder banks, silage and crop-residue management and veterinary outreach. The public's support for small ruminants is also already in place, as seen with the sheep distribution scheme in the state, and Reddy (2020) also stated that the public demanded veterinary services at livestock service centres and livestock and crop insurance.

Table 8. Constraints in adopting ICLS: Garrett ranking (n = 240)

Rank	Constraint	Garrett score
1	Scarcity of fodder in summer months	68.4
2	High cost of concentrate feed	64.2
3	Inadequate veterinary and artificial insemination services	59.7
4	Lack of institutional credit for buying animals	55.1
5	Weak market and unremunerative prices for milk and meat	51.3
6	Disease outbreaks and animal mortality	47.8
7	Shortage of labour for animal care	43.2
8	Shortage of water and grazing land	38.6

Note. Source: field survey, 2019–20. Scores are the mean Garrett scores for all respondents – a higher score indicates a more serious constraint.

6. Conclusion and Policy Implications

This study asked whether integrated crop–livestock systems raise the incomes of Telangana farm households and how they do so. Evidence from 240 households in three districts supports the claim. ICLS households earned 25.1 per cent more than crop-based households and about 20.6 per cent more after controlling for farm size, education, irrigation, credit, extension and district. Matching estimates showed a similar gain of ₹28,900 per household. The gain came mainly from livestock, which supplied a third of adopters' income, while dependence on agricultural wage labour fell from 23.0 to 9.0 per cent. Integration also cut fertiliser spending per hectare by 23.8 per cent, increased manure use, raised net crop income per hectare and generated 21.9 per cent more employment on the farm. Proportional gains

were largest on marginal farms (30.0 per cent), but incomes there remain low, so ICLS should be seen as one part of a livelihood strategy rather than a complete answer.

The policy implications are derived from the restrictions faced by farmers with the highest rank.

1.Fodder security: The most critical factor was summer fodder shortages. Village fodder banks, silage and hay making, utilization of crop residues and cultivation of fodder on irrigated areas in the rabi and summer seasons can increase availability of fodder and reduce the cost of purchased fodder.

2.Animal-health services: Wildlife and artificial insemination coverage should be enhanced using livestock service centres and mobile clinics, as recommended by Reddy (2020), especially in rain fed villages.

3.Credit and insurance: Working-capital credit for animals/livestock insurance should be provided under similar terms and conditions as the crop loan and crop insurance to facilitate small farmers in purchasing and protecting animals/livestock.

4.Markets and collective action: More prevalent among adopters, dairy cooperatives and producer organisations can enhance the price realization for milk, meat and eggs, as well as reduce transaction costs.

5.Convergence and targeting: Targeting marginal and small farmers, and connecting sheds, fodder plots and water to the rural employment guarantee scheme would ensure that support reaches those for whom it is most effective in terms of returns.

The results are subject to some limitations. The data are not based on a multi-year's period and three districts; family labour was not valued as a cost; and income was recalled by the respondents. Regression and matching control only observed characteristics and thus may not account for the income and adoption effects that occur from unobserved characteristics like farmer motivation. Further research should be undertaken on a panel dataset over multiple seasons, with incorporation of price and climate risks, and evaluation of nutritional and environmental impacts, including nutrient balance and greenhouse gas emissions.

Overall, the increasing livestock contribution to the agricultural economy in Telangana is not a mere trend but a clear indication of a shift in the market paradigm. It can be incorporated into a viable income-generating farm system for the small farm household, if feed, animal health, and credit and market support are in place.

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