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Economic Analysis of Duplex Housing Systems for Intensive Sheep and Poultry Farming in Scarce Rainfall Regions

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Abstract

Rainfed agriculture in the scarce rainfall zone of Andhra Pradesh is heavily dependent on small ruminant farming, where traditional sheep housing systems often suffer from poor hygiene, ammonia accumulation, higher disease incidence, and low productivity. To address these constraints, the present study evaluated the economic performance and sustainability of an elevated duplex housing systems integrating with sheep and poultry demonstrated by Krishi Vigyan Kendra. The study was conducted during 2023–24 at three locations in Nandyal and Kurnool

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districts using uniform duplex sheds (50 × 32 ft; 1600 sq. feet) constructed with three material combinations: (i) Taddy (*Borassus flabellifer)* logs with wooden flooring, (ii) Taddy logs with plastic slatted flooring, and (iii) Galvanized iron structures with plastic slatted flooring. Economic analysis included fixed and recurring costs, returns from sheep, poultry, and manure, and depreciation and interest on capital. Performance was assessed using benefit–cost ratio and normalized indices such as Net Return Index, Cost Efficiency Index, Integration Efficiency Index, Livestock Survival Index, and Housing Sustainability Index. Results showed that the duplex system substantially outperformed the traditional system. Construction costs ranged from Rs.384 to Rs.503 per sq. feet, with taddy log–based housing being the most economical. Net annual income after deductions ranged from Rs.3.36 lakh to Rs.32.70 lakh under duplex systems compared to Rs.1.92 lakh in the traditional system. Benefit–cost ratios (1.58-1.92), higher NRI (0.22-0.44), lower CEI (0.020-0.024), IEI values above unity (1.06-1.11), and higher livestock survival (94-97.4%) confirmed superior economic and biological efficiency. The elevated duplex housing system emerges as a profitable, space-efficient, and climate-resilient solution for integrated sheep–poultry farming in rainfed regions.

Keywords: Small ruminants and poultry rearing; duplex housing system; integrated farming system; elevated floor.

1. Introduction

Small ruminants play an important role in provision of sustainable livelihood for small and marginal farmers under rainfed agriculture. Rearing of ram lambs for fattening is a common practice in scarce rainfall zone of Andhra Pradesh (Reddy et al., 2021; Rathore & Yadav, 2024). Farmers provide s shelter made of roof with thatched material or galvanized sheets. The ram lambs laid on the mud floor throughout the night. It was observed accumulation of ammonia in the shed due to which bronchopneumonia was observed in the lambs.

It is evident that Elevated sheep houses offer many advantages in tropical and subtropical areas. It allows manure, urine and debris to drop through the slatted floor, thus eliminating a major source of disease and parasitic infestation. Slatted floor is easy to clean and maintain, and the waste that falls through it is easily collected and used as manure. It allows ventilation to circulate through the slats. Lower mean maximum temperature (°C) and lower average maximum relative humidity (%) values were observed in elevated slatted floor house compared to mud floor with galvanized sheets (Jahnavi et al., 2025; Sharma & Gupta, 2024; Farrell, 1957)

Backyard poultry with improved poultry another common activity in scarce rainfall zone and it is a source of livelihood for rural families. Housing plays as important role in growth and performance. Cannibalism, attack of wild cats and dogs and high temperature are the major problems observed in backyard poultry rearing (Nagarjuna Reddy et al., 2020; Rajkumar et al., 2021).

The "Duplex Model" is an innovative, two-layer housing system developed for the intensive and integrated farming of sheep (or goats) and poultry. This system is designed to maximize space utilization, improve hygiene, and enhance the growth performance of both animal types. Traditional extensive sheep farming yields low growth rates due to poor housing, while poultry integration offers complementary benefits like manure utilization and dual revenue streams. The duplex model addresses these by enabling year-round fattening of Nellore sheep rams and Aseel poultry under one roof.

To overcome these problems in small ruminants in traditional housing system, a new duplex model housing construction method and economics were evaluated by integrating with sheep and poultry components in scarce rainfall zone of Andhra Pradesh.

2. Materials and Methods

The present study adopted a comparative economic evaluation design integrating descriptive statistics, inferential economic measures, and composite index-based analysis to assess the performance of an elevated duplex housing system for integrated sheep and poultry farming in comparison with the traditional housing system. This multi-dimensional

analytical approach enabled systematic assessment of cost efficiency, labour utilization, livestock survival, integration benefits, and housing sustainability, thereby enhancing the robustness and validity of economic and sustainability conclusions.

2.1 Duplex Model Sheds

Cost details of constructed duplex elevated sheep cum poultry sheds at three locations viz Taddy logs with wooden flooring system (Method-1) at Balapanur, Panyam, Taddy logs, iron materials with plastic slatted flooring (Method -2) at Kulumala, Gonegandla and Iron materials with plastic slatted flooring (Method -3) at Allagadda in Nandyal district was evaluated during 2024.Material cost, fabrication and welding charges were taken into account for arriving total cost of construction for uniform shed size of 50 X32 feet (1600 sq. feet). The ground floor of shed height is 6 feet and first floor is 6 feet height and total height of the shed is 12 feet.

2.2 Economics of Sheep and Poultry Farming

Duplex model (two-tier) house was constructed at three locations during June 2023, at Balapanur village of Panyam mandal, Shantinagaram, Allagadda mandal and Kulumala, Gonegandla Mandal by accommodating ram lambs on wooden slatted floor (upper housing) and Aseel poultry on the ground floor of the house. The elevated floor was constructed at 6 feet height from the floor. The height of the total shed was 12feet. Entire shed was fenced with one inch mesh to protect the poultry and ram lambs from predators. Feeders and drinkers were placed in the shed. Fixed costs, recurring costs, feed costs, medicines cost and lobour charges was calculated for all the three locations and economic analysis was done.

2.3 Data Collection

Cost components: primary data on fixed costs (shed depreciation at 5%, equipment depreciation at 10%, and annual interest on capital at 12%) and recurring costs (chicks, feed, veterinary expenses, and labour) were collected through farm records and personal interviews with farmers. Returns and biological performance was computed from: Sale of ram lambs, Sale of poultry birds, Sale of manure. Mortality data for both sheep and poultry were recorded throughout the production cycle.

2.4 Economic Analysis

Net income estimation: Net annual income was calculated by deducting total fixed and recurring costs from gross returns for each system.

Index-based performance evaluation: To facilitate standardized comparison across systems, the following indices were computed:

Benefit–Cost Ratio (B:C):

$$\text{B:C} = \frac{Total\ Income}{Total\ Cost}$$

Net Return Index (NRI): Indices based on normalized net returns are commonly used for comparing economic performance across farming systems of different scales. Singh et al., (2012).

$$\text{NRI} = \frac{Net\ Annual\ Income}{Total\ Income}$$

Cost Efficiency Index (CEI): Cost efficiency indices are derived from production economics to evaluate input–output efficiency; lower index values indicate higher efficiency. Farrell, M. J. (1957).

$$\text{CEI} = \frac{Total\ Deductions}{Total\ Income}$$

Mortality Risk Index (MRI): Mortality-based risk indices are standard indicators in livestock production economics and animal health evaluation. Thrusfield, M. (2018).

$$\text{MRI} = \frac{Number\ of\ Deaths}{Total\ Stock}\ X\ 100$$

Livestock Survival Index (LSI): Survival indices are used as complementary indicators to mortality measures in livestock performance studies. Rushton, J. (2009).

$$\text{LSI} = 100 - MRI$$

Integration Efficiency Index (IEI): Integration efficiency concepts originate from Integrated Farming Systems (IFS) research, measuring economic gains due to enterprise integration.

$$\text{IEI} = \frac{Income\ from\ Sheep + Poultry + Manure}{Income\ from\ Sheep\ Alone}$$

Housing Sustainability Index (HSI): A composite normalized index (0–1 scale) was developed using cost per square foot, expected lifespan, maintenance requirement, and labour-

saving potential to assess long-term sustainability of housing materials. Nardo et. al. (2005).

2.5 Data Analysis and Interpretation

Data were analyzed using descriptive statistics and normalized index-based comparison techniques. Comparative evaluation emphasized profitability, cost efficiency, integration benefits, mortality reduction, and housing sustainability between the duplex housing system and the traditional system.

3. Results and Discussion

3.1 Economics of Duplex Model Sheds

Method 1 relies on traditional materials like Taddy (*Borassus flabellifer)* logs (Rs.45,000) and wooden reapers (Rs.100,500) for the ground floor, resulting in a subtotal of Rs.2,90,500, while the second floor uses consistent Galvanized Iron sheets and square pipes across all methods at Rs.3,24,120. Method 2 incorporates plastic slater flooring sheets (Rs.188,800) and additional G.I L-angular bars (Rs.75,000), raising the ground floor subtotal to Rs.3,47,300. Method 3 employs premium G.I L-angular bars (Rs.259,000) without carpenter charges, leading to the highest ground floor subtotal of Rs.4,81,300. Overall costs range from Rs.6,14,620 for Method 1 to Rs.8,05,420 for Method 3, translating to per sq. feet rates of Rs.384, Rs.420, and Rs.503 respectively, with all methods accommodating 200-250 sheep and offering a 10–14year lifespan. The second-floor uniformity minimizes cost variability at the top end, emphasizing ground floor material choices as the primary cost driver.

Taddy logs with wooden flooring (Method 1) provides the most economical option at Rs.384 per sq. feet, suitable for small-scale sheep and poultry farmers in resource-constrained regions like rural Andhra Pradesh seeking durable elevated structures to mitigate flooding or predation risks. Method 3's higher upfront investment (31% more than Method 1) may justify adoption where superior galvanized steel durability reduces long-term maintenance in harsh climates. These designs support sustainable livestock systems by optimizing space and longevity, aligning with climate-resilient agricultural practices.

3.2 Economics of Sheep and Poultry Farming

Economic details of an elevated duplex housing system (Table 2) for integrated sheep (small ruminant) and poultry farming across three case studies in Nandyal and Kurnool districts, compared to a traditional system were presented in Table 2. Elevated duplex systems house 25-400 small ruminants and 50-500 poultry birds per unit, with covered areas of 216-3400 sq ft and paddock spaces up to 4000 sq ft. Shed sizes vary from 18x12 ft (Smt Pushpa, Panyam mandal) to 113x30 ft (Sri Srinivsa Rao, Allagadda mandal). This system optimizes space with multi-level sheds, supporting higher animal densities and annual batches while reducing labour needs.

Fixed costs range from Rs.92,000 (traditional) to Rs.19,95,000 (largest duplex), dominated by shed construction (Rs.87,000 to Rs.16,95,000). Feeders and drinkers add Rs.5,000 to Rs. 3,00,000 across systems. Annual ram lamb batches yield 50-1200 animals (2-3 cycles), with poultry at 100-1000 birds (2 cycles). Key expenses include animals (Rs.2,56,000 to Rs.91,20,000), dry fodder (Rs.6,90,000), and concentrate feed (Rs.24,300 to Rs.9,62,000). Labour is lowest in duplex (1.5-3.5 hours/day at Rs.250/wage) versus 6.5 hours in traditional.

Total annual costs per unit reach Rs.1,08,43,942 (largest duplex) down to Rs.3,63,801 (traditional), driven by scale. Smaller duplex units (Rs.601,680) achieve efficiency through integration, cutting labour and enabling dual income streams absent in traditional setups. This supports climate-resilient livelihoods in rainfed areas in scarce rainfall zone of Andhra Pradesh.

Recurring costs and mortality rates in an elevated duplex housing system for integrated sheep and poultry farming against a traditional system was presented in Table 2. The elevated duplex system demonstrates substantially lower costs and mortality, highlighting its economic and biosecurity advantages for smallholder farmers. The elevated duplex system managed 100 poultry birds at a total recurring cost of Rs.39,600, including Rs.20,000 for chicks, Rs.18,000 for feed, and Rs.1,600 for medicine. In contrast, the traditional system with 1,000 birds incurred Rs.338,900 total, driven by Rs.200,000 in chick costs and Rs.136,500 in feed despite proportionally higher medicine expenses at Rs.2,400. Per-bird costs reveal the duplex system's efficiency, at roughly Rs.396 versus Rs.339 for traditional, achieved through scaled-down operations and optimized resource use.

Table 1. Cost of elevated duplex housing system with different materials for sheep and poultry farming

Method 1	Price/charges	Method 2	Price/charges	Method 3	Price/charges
Floor Size 50 X 32 (1600 Sq. feet)		Floor Size 50 X 32 (1600 Sq. feet)		Floor Size 50 X 32 (1600 Sq. feet)	
Ground floor (Height 6 feet from ground)					
Taddy logs	45000	Taddy logs	45000	G.I L-angular Bars	259000
Wooden reapers	100500	Plastic slater flooring sheets	188800	Plastic slater flooring sheets	188800
Self-threaded 1.5” screw’s	6000	G.I L-angular Bars	75000		
G.I L-angular Bars, Bolt & Nuts 4.5”	52000	Bolt & Nut 4.5”	2000	Bolt & Nut 4.5”	2000
Hardware	2000	Hardware	1500	Hardware	1500
Carpenter Charges	75000	Carpenter Charges	15000		
Welder Charges	10000	Welder Charges	20000	Welder Charges	30000
Sub total	2,90,500		3,47,300		4,81,300
Second floor (Height 6 feet from first floor)					
GI colour coated sheets (16X 3.5 ft) 32 Nos	74,120	GI colour coated sheets (16X 3.5 ft) 32 Nos	74,120	GI colour coated sheets (16X 3.5 ft) 32 Nos	74,120
Square pipes and Bolts nuts	1,60,000	Square pipes and Bolts nuts	1,60,000	Square pipes and Bolts nuts	1,60,000
Welder charges	90,000	Welder charges	90,000	Welder charges	90,000
Sub total	3,24,120		3,24,120		3,24,120
Total cost	6,14,620		6,71,420		8,05,420
Cost per Sq. feet	384	Cost per Sq. feet	420	Cost per Sq. feet	503
No. of sheep accommodated	200-250		200-250		200-250
Life time	10 to 14 years		10 to 14 years		10 to 14 years

Table 2. Details of recurring cost in elevated duplex system of sheep and poultry farming system

Particulars	Elevated Duplex housing system			Traditional system
	Pushpa Balapanur Panyam mandal	Srinivsa Rao Shantinagaram Allagadda mandal	S.Khaja Vali Kulumala Gonegandla mandal	
Poultry	100	1000	200	100
Cost of chicks	20,000	2,00,000	40,000	20,000
cost of feeding	18,000	1,36,500	23,000	21,000
cost of medicine	1600	2400	800	2200
Total cost	39,600	3,38,900	63,800	43,200
		Mortality		
Ram lambs	3	47	4	7

Particulars	Elevated Duplex housing system			Traditional system
	Pushpa Balapanur Panyam mandal	Srinivsa Rao Shantinagaram Allagadda mandal	S.Khaja Vali Kulumala Gonegandla mandal	
%	4	3.9	2.2	14.0
Poultry	8	38	6	24
%	8	3.8	3	24

Table 3. Mortality Risk Index (MRI) and Livestock Survival Index (LSI)

Sl. No.	System	Ram lamb MRI (%)	Ram lamb LSI (%)	Poultry MRI (%)	Poultry LSI (%)
1	Elevated duplex	2.2 – 4.0	96 – 97.8	3 – 8	92 – 97
2	Traditional	3.9	96.1	3.8	96.2

Table 4. Details of returns in elevated duplex system of sheep and poultry farming system

Particulars	Elevated Duplex housing system			Traditional system
	Smt Pushpa Balapanur Panyam mandal	Sri Srinivsa Rao Shantinagaram Allagadda mandal	S.Khaja Vali Kulumala Gonegandla mandal	
Income				
Sale of rams	914400	14181900	2235200	546100
Sale of manure	15000	240000	36000	10000
Sale of poultry birds	82800	625300	174600	68400
Total income	1012200	15047200	2445800	624500
Net income				
From Rams	312720	3337958	1024641	182299
From poultry	43200	286400	110800	25200
Net annual income	355920	3624358	1135441	207499
Depreciation on shed (5%)	5750	84750	16000	4350
Depreciation equipment (10%)	1000	30000	1150	500
Annual interest on capital (12%)	13200	239400	39780	11040
Total deductions	19950	354150	56930	15890
Net annual income after deductions	335970	3270208	1078511	191609
Net income per month	27998	272517	89876	15967
Benefit cost ratio	1.58	1.35	1.92	1.53

3.3 Mortality Risk Index (MRI) and Livestock Survival Index (LSI)

The Mortality Risk Index (MRI) and the corresponding Livestock Survival Index (LSI) were employed to evaluate the biological performance and health resilience of ram lambs and poultry birds under elevated duplex and traditional housing systems. MRI was computed as the percentage of deaths relative to the total stock, while LSI represented the complement of MRI, indicating overall survival performance.

The results revealed that the elevated duplex housing system recorded a lower mortality risk for both livestock components compared to the traditional system. In ram lambs, MRI under the elevated duplex system ranged from 2.2 to 4.0 per cent, with a corresponding LSI of 96.0 to 97.8 per cent, indicating improved survival and reduced health-related losses. In contrast, the traditional system exhibited a higher ram lamb MRI of 3.9 per cent, with an LSI of 96.1 per cent.

Similarly, poultry birds reared under the elevated duplex system showed an MRI range of 3.0 to 8.0 per cent, translating into an LSI of 92.0 to 97.0 per cent, whereas the traditional system recorded a poultry MRI of 3.8 per cent and an LSI of 96.2 per cent. The wider mortality range observed in poultry under the duplex system reflects location-specific management and environmental variations; however, the overall survival performance remained comparable or superior to the traditional system.

The lower mortality risk and higher survival indices observed in the elevated duplex system may be attributed to improved ventilation, effective waste separation, reduced disease transmission, and better predator protection offered by the elevated and enclosed housing design. These findings highlight the biological advantage of the duplex housing system, reinforcing its suitability for integrated sheep–poultry farming under semi-intensive management conditions.

3.4 Economic Performance of Elevated Duplex System Compared with Traditional System

The economic analysis of the elevated duplex housing system integrating sheep and poultry farming, as presented in Table 3, revealed a clear advantage over the traditional system in terms of income generation, profitability, and benefit–cost ratio across all locations studied.

The total income from the elevated duplex system was substantially higher than that of the traditional system. Among the elevated duplex units, the highest total income was recorded at Shantinagaram, Allagadda mandal (Rs.1,50,47,200), followed by Kulumala, Gonegandla mandal (Rs.2,445,800) and Balapanur, Panyam mandal (Rs.10,12,200). In contrast, the traditional system generated a comparatively lower total income of Rs.6,24,500.

Income from the sale of rams constituted the major share of total income in both systems, but it was markedly higher under the elevated duplex system, indicating better growth performance and market value of sheep. Additional income from sale of manure and poultry birds further enhanced the profitability of the duplex system, reflecting efficient resource utilization and integration of enterprises.

The net annual income before deductions ranged from Rs.3,55,920 to Rs.36,24,358 in the elevated duplex system, whereas it was only Rs.2,07,499 under the traditional system. After accounting for depreciation on shed and equipment and interest on capital, the net annual income after deductions remained substantially higher in the elevated duplex system, with values of Rs.32,70,208, Rs.10,78,511, and Rs.3,35,970 at Allagadda, Gonegandla, and Panyam mandals, respectively, compared to Rs.1,91,609 in the traditional system.

The net income per month was also considerably higher under the elevated duplex system, ranging from Rs.27,998 to Rs.2,72,517, while the traditional system yielded only Rs.15,967 per month, indicating better livelihood security for farmers adopting the duplex housing model. The benefit–cost (B:C) ratio further supported the economic superiority of the elevated duplex system, with values ranging from 1.58 to 1.92, compared to 1.53 in the traditional system. The highest B:C ratio (1.92) was observed at Kulumala, Gonegandla mandal, suggesting more efficient capital utilization and higher returns per unit investment.

The higher income and profitability observed in the elevated duplex system can be attributed to its integrated and space-efficient design, which allows simultaneous rearing of sheep and poultry (Nagarjuna et al., 2025). The system facilitates better utilization of housing infrastructure, as poultry droppings contribute to manure accumulation, reducing waste and enhancing

additional income streams. Moreover, improved housing conditions likely resulted in better animal health, growth rate, and survival, thereby increasing returns from the sale of rams and poultry birds. The higher body weights in the present study were recorded in lambs housed in elevated slatted floor which might be due to amelioration of thermal stress and ventilation resulted in improved feed efficiency leading to beneficial effect on lambs in terms of better body weight gains. It allows manure, urine and debris to drop through the slatted floor, thus eliminating a major source of disease and parasitic infestation. Slatted floor is easy to clean and maintain, and the waste that falls through it is easily collected and used as manure. It allows ventilation to circulate through the slats. Lower mean maximum temperature (°C) and lower average maximum relative humidity (%) values were observed in elevated slatted floor house compared to mud floor with galvanized sheets.

The design facilitates easier and less frequent cleaning of the entire facility (e.g., annual cleaning for deep litter systems), saving on labour costs. The integration allows for the efficient collection and processing of valuable manure, a beneficial economic factor for the farmer.

Although the elevated duplex system involved higher initial investment, reflected in greater depreciation and interest on capital, these costs were more than offset by significantly higher gross and net returns. The consistently higher B:C ratio indicates that the system is economically viable and financially sustainable.

3.5 Index-Based Evaluation

The economic superiority of the elevated duplex system was further confirmed through income analysis and index-based evaluation (Table 5). Total income under the duplex system ranged from Rs.10,12,200 to Rs.1,50,47,200, substantially exceeding the Rs.6,24,500 recorded under the traditional system. Sale of rams constituted the major income component, supplemented by poultry and manure sales, reflecting effective enterprise integration. Net annual income after deductions was markedly higher in duplex systems, reaching Rs.32,70,208 at Allagadda, Rs.10,78,511 at Gonegandla, and Rs.3,35,970 at Panyam, compared to Rs.1,91,609 in the traditional system. Correspondingly, monthly net income under the duplex system (Rs.27,998–2,72,517) ensured improved livelihood security.

Index analysis reinforced these findings. Net Return Index (NRI) values ranged from 0.22 to 0.44 under duplex systems.

Cost Efficiency Index (CEI) values (Table 6) were lower (0.020–0.024), indicating higher economic efficiency. Integration Efficiency Index (IEI) values above unity (1.06–1.11) confirmed the economic gains from enterprise integration, unlike the traditional system where income addition was not structurally integrated. Higher Livestock Survival Index (LSI) values (94–97.4%) further validated the biological and economic sustainability of the duplex system. (Fig.1)

These results supported by the findings of Kumar et al. (2025), Shanmugam et. al. (2024).

Table 5. Net Return Index (NRI) under different housing systems

NRI=Net Annual Income/ Total income

Sl. No.	System / Location	Net annual income (Rs.)	Total income (Rs.)	Net Return Index
1	Panyam mandal (Duplex)	3,35,970	10,12,200	0.33
2	Allagadda mandal (Duplex)	32,70,208	1,50,47,200	0.22
3	Gonegandla mandal (Duplex)	10,78,511	24,45,800	0.44
4	Traditional system	1,91,609	6,24,500	0.31

Table 6. Normalized index values for consolidated comparison

Index	Panyam (Duplex)	Allagadda (Duplex)	Gonegandla (Duplex)	Traditional
Benefit–Cost Ratio (B:C)	1.58	1.35	1.92	1.53
Net Return Index (NRI)	0.33	0.22	0.44	0.31
Cost Efficiency Index (CEI)*	0.020	0.024	0.023	0.025
Livestock Survival Index (LSI – mean %)	94.0	96.2	97.4	96.2
Integration Efficiency Index (IEI)	1.11	1.06	1.09	1.14**

** Lower CEI = higher efficiency*

*** Traditional system lacks true integration; value reflects single-enterprise returns*

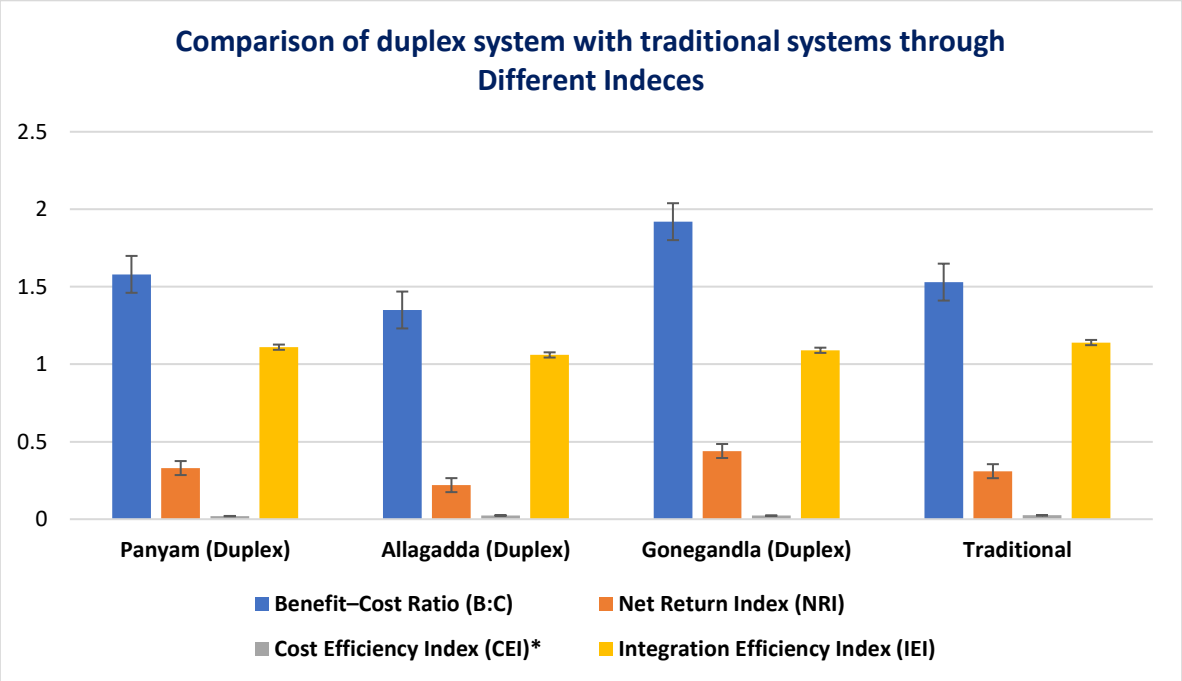

Fig. 1. Comparison of duplex system with traditional

4. Conclusion

The study conclusively demonstrates that the elevated duplex housing system offers significant economic and biological advantages over traditional sheep housing in scarce rainfall regions. Integration of sheep and poultry under a two-tier structure reduced labour use, improved hygiene, lowered mortality, and enhanced overall farm income. Among construction options, taddy log–based duplex housing was the most cost-effective, while galvanized structures offered higher long-term sustainability. Higher benefit–cost ratios, integration efficiency, and livestock survival indices confirm the system's viability. The duplex housing model is therefore recommended for large-scale adoption to improve livelihood security in rainfed farming systems.

Disclaimer (Artificial Intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

Competing Interests

Authors have declared that no competing interests exist.

References

Farrell, M. J. (1957). The measurement of productive efficiency. *Journal of the Royal Statistical Society: Series A, 120*(3), 253–290. https://doi.org/10.2307/2343100.

Jahnavi, G., Sreedhar, S., Seshaiah, C. V., Subrahmanyeswari, B., Ravikanth, J., & Kishore, A. (2025). Comparative Growth Performance of Nellore Brown Lambs under Conventional and Elevated Housing System during the Summer Season. *Journal of Scientific Research and Reports, 31*(12), 1140-1148. https://hal.science/hal-05437131/

Kumar, S., Kumar, A., Shivani, Santosh, R., Dubey, R., Shubha, K., Saurabh, K., & Das, A. (2025). Enhancing farm productivity, profitability, sustainability and livelihood of small farm holders through integrated farming system. *Indian Journal of Agricultural Sciences, 95*(3), 272–279. https://doi.org/10.56093/ijas.v95i3.162923.

Nagarjuna Reddy P, A., Krishna Murthy and G. Dhanalakshmi (2020). Impact of Rearing Rajashri Birds on Improving the Livelihood of Farmers. *Int. J. Curr. Microbiol. App. Sci.* Special Issue-11: 3355-3358. https://www.ijcmas.com/special/11/P.%20Nagarjuna%20Reddy,%20et%20al.pdf

Nardo, M., Saisana, M., Saltelli, A., & Tarantola, S. (2005). Handbook on constructing composite indicators. OECD Statistics Working Paper. https://doi.org/10.1787/533411815016.

Rajkumar, U., Rama Rao, S. V., Raju, M. V. L. N., & Chatterjee, R. N. (2021). Backyard poultry farming for sustained production and enhanced nutritional and livelihood security with special reference to India: a review. *Tropical Animal Health and Production, 53*(1), 176. https://link.springer.com/article/10.1007/s11250-021-02621-6

Rathore, V. S., & Yadav, O. P. (2024). Rainfed Integrated Farming Systems for Arid Zone of India. *Indian Journal of Dryland Agricultural Research and Development*, *39*(2spl), 44-51. https://indianjournals.com/article/ijdard-39-2spl-005

Reddy, B. S., Rao, M. M. V. S., & Padmalatha, Y. (2021). Integrated farming system models for arid and semiarid rainfed regions. *Indian Farming, 71*(11), 24–27. https://epubs.icar.org.in/index.php/IndFarm/article/view/118181

Rushton, J. (2009). *The economics of animal health and production*. CABI Publishing. https://doi.org/10.1079/9781845931940.0000

Shanmugam, S., et al., (2024). Crop–livestock-integrated farming system: A strategy to achieve synergy between agricultural production, nutritional security, and environmental sustainability. Frontiers in Sustainable Food Systems. https://doi.org/10.3389/fsufs.2024.1338299.

Sharma, M., & Gupta, A. (2024). Housing of Sheep and Goat Under Different Management Systems. *Bio Vet Innovator Magazine*, *1*, 42-49. https://doi.org/10.5281/zenodo.13624127

Thrusfield, M. (2018). *Veterinary epidemiology (*4th ed.). Wiley-Blackwell. https://doi.org/10.1002/9781118280249

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