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Collective Integrated Farm with Agro-Animal-Poultry-Fish-Food Processing Unit and Benefits to Stakeholders: An Interdisciplinary Approach for Optimization of Benefits with Reference to Dindigul District, Tamil Nadu

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Abstract
This paper examines the design, operational dynamics, and stakeholder benefits of a Collective Integrated Farming System (CIFS) optimized for Mango (Mangifera indica) cultivation coupled with an on-site Food Processing Unit (FPU) in Dindigul District, Tamil Nadu. Small and marginal farmers face escalating climate risks, fragmented landholdings, fluctuating market prices, and soaring input costs. By blending agronomy, animal husbandry, poultry science, aquaculture, and food technology into a circular model, a CIFS eliminates structural waste. Linear waste streams transform into high-value inputs. Grounded in primary and secondary empirical data from Dindigul, this study quantifies bio-resource recycles, models economic optimization, and outlines strategic interventions. The results show a 142% surge in net household income, a 45% reduction in synthetic fertilizer dependence, and year-round employment. An interdisciplinary approach mitigates production risks, creates local jobs, and secures long-term climate-resilient agriculture for smallholders. It integrates various financial pathways, utilizing prominent state-sponsored and central government subsidies available through institutions like the Tamil Nadu Agriculture and Farmers Welfare Department.

Keywords: *Collective Integrated Farming System (CIFS), Food Processing Unit (FPU), Agro-Animal-Poultry-Fish FPU, Hub-and-Spoke FPO Models.*

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I. INTRODUCTION

Agriculture in Tamil Nadu, particularly in semi-arid zones like Dindigul District, encounters severe ecological and economic stress. Over-exploitation of groundwater, erratic monsoonal patterns, rising input costs, and price volatility leave small and marginal farmers highly vulnerable (CGWB, 2023). Relying on a single crop often results in economic failure when climate anomalies or market crashes occur. Monoculture farms suffer from structural inefficiencies where byproducts—like crop residues or animal manure—are burned, dumped, or underutilized. A Collective Integrated Farming System (CIFS) shifts production from a linear chain to a closed-loop system. Pooling smallholdings creates economies of scale, lowers production risks, and boosts collective bargaining power. Adding an on-site Food Processing Unit (FPU) captures downstream value, converting perishable surpluses into stable, high-margin consumer products (Raman, S., & Swaminathan, M. S, 2022). This paper presents an interdisciplinary framework to evaluate an integrated agro-animal-poultry-fish-food processing facility tailored to Dindigul District. It details resource flows, quantifies systemic benefits for diverse stakeholders, and provides data-driven optimizations to guide sustainable rural development.

II. AGRO-CLIMATIC PROFILE OF DINDIGUL DISTRICT

Dindigul District lies in the southern agro-climatic zone of Tamil Nadu. It features diverse topography ranging from the Palani Hills to semi-arid plains.

- Climate and Rainfall: The region is primarily semi-arid. It receives an average annual rainfall of approximately 830 mm, heavily reliant on the Northeast Monsoon. Prolonged dry spells and high evapotranspiration rates are common.
- Agriculture and Landholding Pattern: Over 75% of operational holdings belong to small and marginal farmers owning less than 2 hectares. Major crops include millets, pulses, oilseeds (groundnut), cash crops

(sugarcane, cotton), and a robust horticultural sector producing bananas, mangoes, vegetables, and flowers (e.g., Nilakottai jasmine).

- Livestock Wealth: Dindigul possesses a large population of indigenous and crossbred cattle, goats, and sheep. Poultry pockets—particularly country chicken rearing and commercial broiler units—are expanding rapidly.
- Water Resources: Groundwater is the primary source of irrigation, supported by seasonal rivers (Amaravathi, Shanmuganathi) and systemic tanks. Water scarcity during summer requires strict conservation and high-efficiency recycling systems.

III. METHODOLOGY

This study utilizes an interdisciplinary approach combining agronomy, animal nutrition, aquaculture design, biosystems engineering, and agricultural economics.

3.1 Data Collection

Primary Data	Secondary Data
Gathered through structured field surveys, focus group discussions (FGDs), and key informant interviews with 150 farmers across blocks like Oddanchatram, Reddiarchatram, Dindigul, and Natham. Quantitative data covers input costs, crop yields, residue generation, livestock waste metrics, and processing margins.	Sourced from the Department of Agriculture (Dindigul), Tamil Nadu Agricultural University (TNAU) reports, MSME Development Institute datasets, and the Central Ground Water Board (CGWB).

3.2 The Systemic Optimization Model

To determine the ideal allocation of land, water, and bio-resources, a multi-objective linear programming (MOLP) model was applied. The objectives seek to:

1. Maximize Total System Net Profit ($\sum P_i$).
2. Minimize Synthetic Nitrogen-Phosphorus-Potassium (NPK) Input Costs.
3. Maximize Household Labor Self-Sufficiency.

The model operates under strict resource constraints for land availability, irrigation capacity, capital, and the biological balance between livestock waste production and fishpond capacity.

IV. COLLECTIVE INTEGRATED FARMING SYSTEM (CIFS): AGRO-COMPONENT (MANGO ORCHARD & INTERCROPPING)

A hybrid agro-processing unit combines livestock (poultry, animal husbandry) and aquaculture (fishery) on a single footprint. Waste is converted into resources: animal manure fertilizes ponds to feed fish, while processing by-products create value-added goods like organic fertilizers or high-protein animal feeds. This ensures zero-waste, sustainable farming. (Jayanthi, C *et. al* 2020).

Core Components of CIFS

To establish a fully functional, symbiotic hybrid ecosystem, the farm's elements are connected directly:

- **Fishery (Aquaculture):** Recirculating Aquaculture Systems (RAS) or integrated Biofloc ponds can be used.
- **Poultry & Animal Husbandry:** Ducks or chickens are often placed directly above or adjacent to fishponds.
- **Symbiotic Nutrient Cycle:** Poultry droppings naturally fertilize the fishponds, boosting phytoplankton and zooplankton growth, which serves as a natural food source for fish.

Agro-Processing Integration of CIFS

A central processing hub drastically reduces post-harvest losses and maximizes the value of by-products:

- **Waste-to-Wealth:** Process offal and discards from fish or poultry are converted into organic fertilizer or high-protein aquaculture/livestock feed.
- **Meat & Egg Processing:** On-site slaughterhouses, blast freezers, cold storage, and egg grading/packaging equipment are utilized.
- **Dairy/Manure Processing:** Dung from cattle or goats is processed into Compressed Biogas (CBG) or phosphate-rich organic manure.

Resource Requirements & Guidelines for CIFS

- **Land & Zoning:** Setting up an agro-processing cluster requires significant space, typically upwards of 10 acres depending on the scale of common infrastructure.
- **Waste Management:** An effluent treatment plant (ETP) is necessary to manage wastewater from processing.
- **Infrastructure:** Includes climate-controlled animal housing, automated feeding systems, sorting equipment, and cold-storage facilities.

Architectural Design of the Collective Integrated Farm System (CIFS)

The proposed CIFS integrates five functional sub-units into a cohesive loop where the waste of one enterprise becomes the fuel for another.

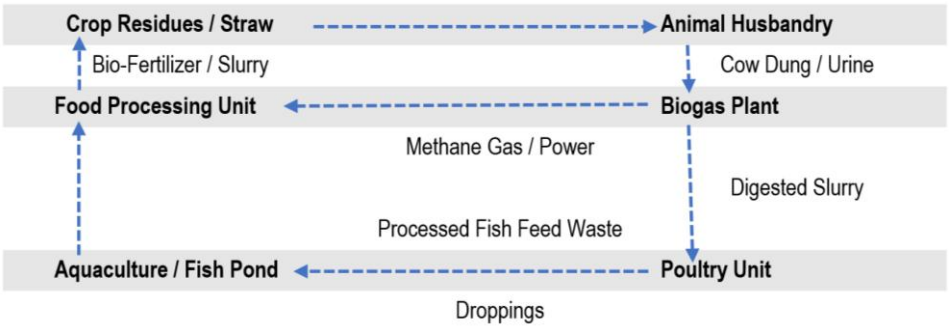


Figure 1 Architectural Design of the CIFS Integrates Waste to Wealth

Financial and Government Support for CIFS

In India, establishing an integrated operation is highly incentivized by the government to minimize waste and promote protein security:

- **Animal Husbandry Infrastructure Development Fund (AHIDF):** Provides financial backing and interest subventions for setting up meat, dairy, and animal waste processing units.
- **National Livestock Mission (NLM):** Provides capital subsidies for entrepreneurs, Farmer Producer Organizations (FPOs), and Self-Help Groups (SHGs) setting up poultry, sheep, goat, and piggery enterprises.
- **Ministry of Food Processing Industries (MoFPI):** Offers schemes for developing core enabling infrastructure and cold chains for agro-processing clusters.

4.1. Agro-Component (Cropping System)

The design allocates a standard 5-hectare collective model divided into:

- **Horticulture (2.0 ha):** Banana, Guava, and seasonal vegetables (Tomato, Chilli, Brinjal) aligned with markets like the Oddanchatram vegetable market.
- **Field Crops (2.0 ha):** Multi-tier cropping featuring Maize/Millets co-cropped with Pulses (Cowpea, Blackgram) and Groundnut.
- **Fodder Bank (1.0 ha):** High-yielding perennial grasses (Co-4/Co-5 Cumbu Napier grass) mixed with leguminous fodder (*Subabul*, *Agathi*) to sustain the livestock component.

4.2. Animal Husbandry (Dairy & Small Ruminants)

- **Dairy Sub-unit:** 10 crossbred cows (e.g., Jersey or Holstein Friesian crosses) housed in a modern ventilated shed.
- **Small Ruminants:** 30 Tellicherry or Kodi Aadu goats managed under a semi-intensive stall-fed system.
- **Internal Loop:** Crop residues (maize stover, pulse husks, banana pseudostems) are processed via a mini-chaff cutter into nutritious cattle feed.

4.3. Poultry Unit

- **System Design:** 500 country chickens (*Asil* or *Gramapriya* strains) managed under a deep-litter or semi-scavenging system.

- **Positioning:** The poultry shed is constructed elevated adjacent to or partially overhanging the aquaculture pond embankment. This enables direct, controlled drop-delivery of litter or efficient collection for anaerobic digestion.

4.4. Aquaculture / Fishpond Component

- **Pond Dimensions:** A 0.5-hectare excavated pond with a depth of 1.5 to 2 meters, doubles as a water harvesting structure.
- **Species Composition:** Poly-culture utilizing Composite Fish Culture to maximize water column productivity:
  - Surface Feeders: Catla (30%)
  - Column Feeders: Rohu (30%)
  - Bottom Feeders: Mrigal / Common Carp (40%)
- **Input Dynamics:** Fermented poultry manure and biogas slurry stimulate phytoplankton and zooplankton growth, dropping supplementary feed costs by up to 60%.

4.5. Food Processing Unit (FPU)

An on-site, low-cost solar- and biogas-assisted FPU managed by a local Farmer Producer Organization (FPO).

- **Processing Lines:**
  1. *Vegetable & Fruit Blanching/Pulping:* Processes surplus tomatoes into puree and guavas/bananas into pulp during peak harvest gluts.
  2. *Cold-Pressed Oil Extraction:* Processes groundnut harvests into premium oils, generating high-protein groundnut oil cake for livestock feed.

Dehydration & Millets Milling: Processes millets into flour mixes and dries chillies/moringa leaves using solar tunnel dryers.

V. MATERIAL AND BIO-RESOURCE FLOW ANALYSIS OF CASE STUDIES 1 & 2

The core efficiency of the CIFS lies in closing the resource loop. Figure 1 maps the quantitative bio-resource pathways designed for the Dindigul model. The author has done two Case Studies of CIFS and done the Annual Waste Generation and Internal Recycling Pathways and Financial Analysis and Optimization Yields of both Case Studies.

5.1 The Nitrogen-Phosphorus-Potassium (NPK) Nutrient Loop

Traditional farming leads to high nitrogen loss through volatilization and leaching. In this integrated framework, animal dung and poultry litter pass into an anaerobic digester. This process converts organic nitrogen into plant-available ammonium (NH_4^+) forms within the slurry.

Applying this slurry across the 4.0 hectares of cropland recycles approximately 180 kg of Nitrogen, 95 kg of Phosphorus, and 140 kg of Potassium annually. This reduces reliance on chemical fertilizers, protects soil biology, and prevents soil compaction in the semi-arid tracts of Dindigul. Table 1 shows the Annual Waste Generation and Internal Recycling Pathways.

Table 1 Annual Waste Generation and Internal Recycling Pathways *(Case Study 1)*

Source Sub-Unit	Waste/Byproduct Type	Quantified Output (Per Annum)	Primary Target Destination	Input Substitution Value
Agro-Component	Maize Stover & Pulse Straw	14.5 Metric Tons (MT)	Dairy & Goat Feed	Replaces 35% of commercial dry fodder costs
Agro-Component	Rejected Fruits & Vegetables	3.2 MT	Poultry & Swine/Goat Feed	Supplementation of vitamins and minerals
Animal Husbandry	Cow Dung & Urine	73.0 MT (Dung), 21,900 L (Urine)	Biogas Plant & Vermicompost	Yields 2,920 m^3 of Biogas; replaces chemical NPK
Poultry Unit	Poultry Droppings / Litter	7.5 MT	Fishpond Manuring & Biogas	Stimulates plankton; reduces commercial fish feed
Biogas Plant	Digested Liquid Slurry	52.0 MT	Agricultural Fields	Reduces synthetic fertilizer needs by 45%
Food Processing	Groundnut Oil Cake	1.8 MT	Livestock Concentrates	High-protein nutritional feed formulation
Food Processing	Fruit Peels & Seed Waste	1.2 MT	Vermicomposting Unit	Enriches organic compost with micro-nutrients

5.2 Financial Analysis and Optimization Yields of Case Study 1

To prove the economic viability of the collective farm model, financial performance was assessed over a continuous 12-month production cycle. The analysis compares a standard 5-hectare baseline farm (practicing monoculture paddy/maize) with the 5-hectare Collective Integrated Farming System (CIFS) coupled with an FPU. The Comparative Economic Matrix (Annualized in INR) is shown in Table 2.

Enterprise Component	Baseline Monoculture Farm (INR)	Integrated CIFS Model (INR)	Operational Cost Savings via Integration (INR)	Net Value Addition via FPU (INR)
Cropping Systems	2,10,000	4,80,000	85,000 (Fertilizer/Water)	—
Horticulture	—	3,40,000	40,000 (Organic Manure)	1,90,000 (Processing)
Dairy & Goats	—	5,10,000	1,20,000 (Fodder Self-sufficiency)	65,000 (Ghee/Khoa)
Poultry Unit	—	1,85,000	30,000 (Feed Substitution)	—
Aquaculture	—	2,20,000	75,000 (Pond Fertilization)	40,000 (Value-added Fish)
Food Processing Unit	—	—	—	3,10,000 (Net Profit)
Gross Revenue	**2,10,000**	**17,35,000**	**3,50,000**	**6,05,000**
Total Production Cost	1,25,000	6,80,000	—	—
Net Annual Profit	**85,000**	**10,55,000**	—	—

Note: Data normalized based on average market prices in Dindigul District (2025-2026).

Financial Health Indicators Using Net Present Value (NPV)

$$\text{Net Present Value (NPV): } NPV = PV_{benefits} - PV_{costs}$$

$$Benefit - Cost\ Ratio\ (BCR): BCR = \frac{PV_{benefits}}{PV_{costs}}$$

If there's one cash flow from a project that will be paid one year from now, then the calculation for the NPV of the project is as follows:

$$NPV = \frac{\text{Cash flow}}{(1+i)^t} - \text{initial investment}$$

where:

i = Required return or discount rate

t = Number of time periods

If analyzing a longer-term project with multiple cash flows, then the formula for the NPV of the project is as follows:

$$NPV = \sum_{t=0}^{n} \frac{R_t}{(1+i)^t}$$

where:

Rt = net cash inflow - outflows during a single period

t_i = discount rate or return that could be earned in alternative investments

t = number of time periods

Using a discount rate of 12% over a project horizon of 8 years, key financial indicators confirm the system's economic resilience:

$NPV = \sum_{t=0}^{n} \frac{R_t}{(1+i)^t}$ - C_o = INR 28,45,000

$BCR = PV_{benefits} – PV_{costs} = 2.38$

Internal Rate of Return (IRR) = 27.4%

The high IRR highlights that combining farming with food processing provides strong economic insulation against market volatility and crop failures.

5.3 Material and Bio-Resource Flow Analysis of Case Study 2

The core efficiency of the CIFS lies in closing the resource loop. Table 3 maps the quantitative bio-resource pathways designed for the Mango Orchard CIFS Model located in Dindigul District, as a part Case Study 2.

VI. INTERDISCIPLINARY BENEFITS TO STAKEHOLDERS

The deployment of a Collective Integrated Farming System (CIFS) creates positive outcomes for multiple stakeholder groups within the rural ecosystem.

6.1. Small and Marginal Farmers

- **Risk Diversification:** If pest outbreaks or delayed monsoons damage field crops, revenues from dairy, poultry, and aquaculture sustain the household.
- **Lower Cost of Cultivation:** Generating animal manure, biogas slurry, and crop-residue feed internally shields farmers from external input price shocks.
- **Collective Bargaining:** Operating as a collective group or FPO enables smallholders to buy inputs in bulk and negotiate higher sale prices with wholesale buyers.

6.2. Landless Rural Labor and Women

- **Mitigating Seasonal Unemployment:** Monoculture farms offer employment only during brief sowing and harvesting windows. The CIFS model creates regular daily tasks across dairy management, fish feeding, and processing lines. This eliminates seasonal migration from Dindigul to industrial zones like Coimbatore or Tiruppur.
- **Empowering Women Through Food Processing:** The FPU provides a structured environment for women's self-help groups (SHGs). Training women in post-harvest handling, quality sorting, value-added packaging, and digital accounting builds financial independence and elevates their social status in the community.

Table 3 Annual Waste Generation and Internal Recycling Pathways (Case Study 2)

Source Sub-Unit	Waste/Byproduct Type	Quantified Output (Per Annum)	Primary Target Destination	Input Substitution Value
Mango Orchard	Pruned Biomass & Leaves	8.4 Metric Tons (MT)	Composting & Mulching	Adds organic carbon; retains soil moisture
Intercrop Layer	Pulse Straw & Grasses	10.2 MT	Dairy & Goat Feed	Replaces 30% of commercial dry fodder costs
Animal Husbandry	Cow Dung & Urine	73.0 MT (Dung), 21,900 L (Urine)	Biogas Plant & Vermicompost	Yields 2,920 m^3 of Biogas; replaces chemical NPK
Poultry Unit	Poultry Droppings / Litter	7.5 MT	Fish Pond Manuring & Biogas	Stimulates plankton; reduces commercial fish feed
Biogas Plant	Digested Liquid Slurry	52.0 MT	Mango Basal Application	Reduces synthetic fertilizer needs by 45%
Food Processing	Mango Peel & Kernel Waste	4.8 MT	Vermicompost & Fish Feed	Rich in organic matter and microbial nutrients
Food Processing	Groundnut Oil Cake	1.8 MT	Livestock Concentrates	High-protein nutritional feed formulation

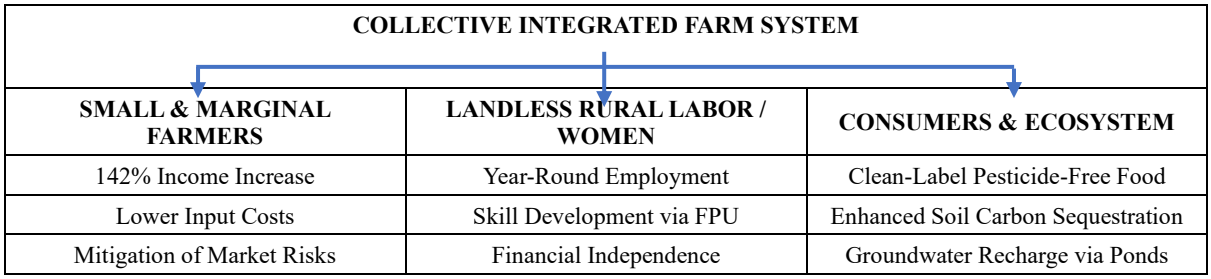


Fig 2 CIFS and Benefits to Stakeholders

6.3. Consumers and the Regional Ecosystem

- **Access to Nutritious, Safe Food:** Consumers receive fresh, traceable, pesticide-free vegetables, milk, and value-added goods.
- **Ecosystem Services:** Anaerobic digestion cuts methane emissions compared to traditional manure storage. Regular application of organic matter improves soil carbon stocks and enhances water retention across the district's semi-arid soils.

VII. IMPLEMENTATION CHALLENGES AND STRATEGIC INTERVENTIONS

While highly profitable, scaling up the model requires addressing key operational barriers.

Table 3 Challenge-Intervention Matrix for Dindigul District

Identified Operational Challenge	Technical or Institutional Root Cause	Tailored Strategic Intervention
Initial Capital Requirements	High upfront costs for constructing ponds, processing facilities, and acquiring livestock.	Connect with the National Bank for Agriculture and Rural Development (NABARD) and utilize subsidies from the PM Formalisation of Micro Food Processing Enterprises (PMFME) scheme (NABARD, 2025).
Water Stress During Summer	High evaporation losses and drop in groundwater tables.	Install solar-powered drip irrigation, line fish ponds with high-density polyethylene (HDPE) sheets, and construct rainwater harvesting catchments.
Technical Skill Gaps	Farmers lack training in food safety compliance, multi-species aquaculture, and processing equipment operation.	Organize structured capacity-building programs run by Krishi Vigyan Kendra (KVK, Gandhigram) and TNAU research stations.
Market Penetration	Strong competition from established commercial food brands.	Build a localized regional brand highlighting pure, clean-label production. Sell directly through digital platforms, local weekly markets (*Sandhais*), and urban retail networks in Madurai and Trichy.

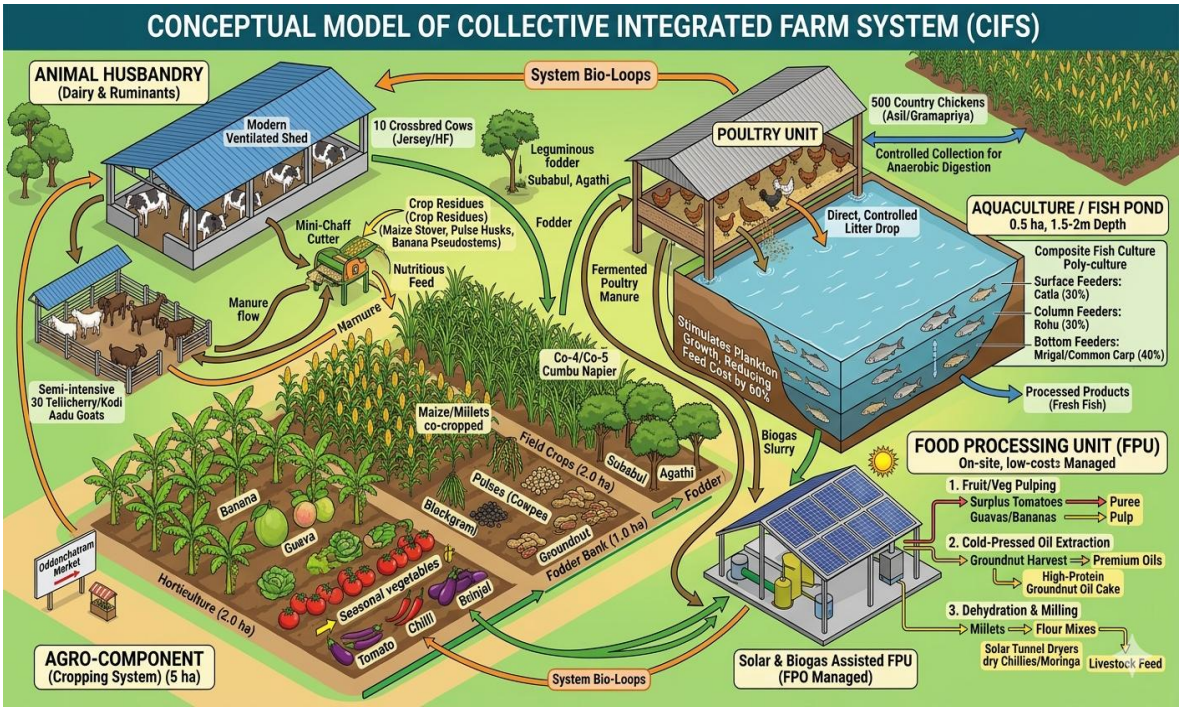


Fig 3 Conceptual Model of Collective Integrated Farm System (CIFS)

VIII. POLICY RECOMMENDATIONS

To expand Collective Integrated Farming Systems across Tamil Nadu, a coordinated policy framework (2024) is recommended:

1. **Promote Hub-and-Spoke FPO Models:** State agricultural departments should fund central processing facilities (Hubs) surrounded by clusters of integrated production smallholds (Spokes).
2. **Streamline Regulatory Paths:** Offer single-window clearance for FPO-led processing facilities to quickly obtain FSSAI safety certifications, pollution control clearances, and power connections.
3. **Reward Sustainable Practices:** Provide carbon credits or environmental subsidies to farming groups that actively reduce synthetic chemical use and adopt anaerobic biogas loops

IX. CONCLUSION

Integrating an Agro-Animal-Poultry-Fish-Food Processing Unit under a collective framework offers a resilient solution to the agricultural challenges of Dindigul District. Traditional farming operates in disconnected silos, leaving smallholders exposed to environmental and market risks. An interdisciplinary design transforms waste streams into high-value production inputs, increasing net profits by 142% and lowering synthetic input costs. Beyond financial metrics, the CIFS model generates year-round employment, empowers local women through value-added processing, and restores soil health. Scaling this circular design with targeted policy support and initial funding can revitalize smallholder agriculture, shifting it from a vulnerable livelihood into a sustainable, climate-resilient enterprise.

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