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Smallholder poultry production and rural livelihoods in the Lower Mekong region: Opportunities, challenges, and pathways for sustainable development

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ABSTRACT

Smallholder poultry production contributes to food security, household income, employment, and livelihood diversification across the Lower Mekong region. However, its sustainability is constrained by feed costs, infectious diseases, limited veterinary and extension services, inadequate genetic improvement, climate-related pressures, and restricted market access. This review synthesizes available evidence on smallholder poultry production and rural livelihoods in Lao PDR, Cambodia, Thailand, and Vietnam, examining production systems, socioeconomic contributions, major constraints, technological innovations, and regional development priorities. The literature indicates substantial diversity in production systems, ranging from traditional backyard and free-range flocks to semi-intensive and small-scale commercial enterprises. Poultry provides important nutritional and economic benefits, particularly for resource-constrained households and women, although outcomes vary according to production conditions, household resources, and market participation. Emerging opportunities include alternative feed resources, precision nutrition, indigenous genetic improvement, preventive animal health management, climate-smart practices, circular agriculture, and digital technologies. Nevertheless, their adoption requires context-specific interventions, accessible services, institutional support, and economic feasibility. Strengthening research collaboration, gender-inclusive policies, veterinary infrastructure, and regional value chains is essential to improving productivity, resilience, and environmental sustainability. Integrated development strategies can enhance poultry's contribution to sustainable rural livelihoods throughout the Lower Mekong region.

KEYWORDS: *Smallholder poultry production; Rural livelihoods; Food security; Sustainable development; Lower Mekong region*

1. Introduction

Agriculture is fundamental to rural livelihoods in the Lower Mekong region, particularly in Lao PDR, Cambodia, Thailand, and Vietnam, where households depend on crop production, livestock, fisheries, and natural resources for food security and income generation. However, these livelihoods face increasing pressures from climate variability, environmental degradation, natural hazards, market instability, and unequal access to productive resources and agricultural services (Pal et al., 2024). Livestock production helps diversify household income, improve access to animal-source foods, and strengthen financial security. Among livestock enterprises, poultry is particularly accessible because it generally requires less land and initial investment than larger livestock species and can be integrated into existing smallholder farming systems (Keohavong, 2026a, 2026b). Smallholder poultry production contributes to rural livelihoods through meat and egg provision, supplementary income, employment, and household entrepreneurship (Yitayih et al., 2023; Truong et al., 2021; Houghton et al., 2025). Chickens and ducks are commonly raised under backyard, free-range, semi-intensive, and small-scale commercial systems, with management shaped by

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household labour, financial resources, feed availability, and market access (Yitayih et al., 2023; Truong et al., 2021). Beyond providing animal-source protein and essential micronutrients, poultry generates income for household expenditure, education, healthcare, and agricultural investment (Yitayih et al., 2023; National Institute of Statistics [NIS], 2022). It can also support women's participation in livestock management and household economic activities (Yitayih et al., 2023; Nguyen, 2025). In Lao PDR, traditional backyard production remains important, particularly for women and young people (Nguyen, 2025), while approximately 75% of agricultural household holdings in Cambodia reported raising poultry (NIS, 2022). These contributions establish poultry as an important component of household nutrition, livelihood diversification, and economic resilience (Keohavong et al., 2026a, 2026b; Yitayih et al., 2023; Houghton et al., 2025; Pal et al., 2024).

Despite their shared importance, poultry production systems vary across the region according to geographical conditions, household resources, production objectives, indigenous genetic resources, and market development (Yitayih et al., 2023; Esatu et al., 2025; Ngo Thi Kim Cuc et al., 2025). Traditional backyard systems generally involve small flocks of indigenous or locally adapted chickens and ducks, relying on household leftovers, local feed resources, agricultural by-products, and supplementary commercial feeds (Yitayih et al., 2023; Charoensook et al., 2021). Their integration with crop cultivation and other livestock enterprises facilitates resource utilization and livelihood diversification (Huy et al., 2023; Manilay et al., 2021). Conversely, small-scale commercial systems typically involve larger flocks, greater dependence on purchased feeds and improved breeds, and stronger market engagement (Truong et al., 2021; Yitayih et al., 2023; Esatu et al., 2025). Although commercialization offers income and production opportunities, it can increase input costs and financial vulnerability (Truong et al., 2021; Houghton et al., 2025). Evidence from Vietnam's Mekong Delta illustrates these trade-offs, with native chicken producers facing high feed expenditure, flock mortality, and limited profitability (Truong et al., 2021). Accordingly, productivity and livelihood outcomes depend on the interaction of socioeconomic, environmental, and institutional conditions (Huy et al., 2023; Yitayih et al., 2023; Esatu et al., 2025).

Nevertheless, smallholder poultry systems face interconnected nutritional, technical, health-related, economic, and institutional constraints. High feed costs, inconsistent feed quality, inadequate veterinary and extension services, infectious diseases, limited genetic improvement, weak biosecurity, and restricted market and financial access can undermine productivity and profitability. Feed constraints are particularly important in commercialized systems, where purchased feeds represent a major expense, and in backyard systems, where variable feed quality may limit productivity (Keohavong et al., 2026b; Keohavong, 2026b). In Cambodia, limited veterinary service accessibility is a concern, with poultry receiving inadequate attention despite being the most commonly raised livestock species (McKinley et al., 2026). In Lao PDR, high flock mortality, imported-feed dependence, limited extension services, inadequate genetic resources, and threats from highly pathogenic avian influenza and Newcastle disease remain important challenges (Nguyen, 2025). Floods, droughts, and rising temperatures further threaten agricultural productivity and livelihood resilience across the region (Pal et al., 2024). These interacting constraints can intensify production risks, reduce household income, and restrict technology adoption. At the same time, technological and institutional innovations offer pathways to improve productivity and sustainability. These include locally available alternative feed ingredients, improved nutritional management, conservation of indigenous genetic resources, vaccination, biosecurity, and climate-smart practices (Keohavong, 2026a; Keohavong et al., 2026b). Circular agriculture can improve resource-use efficiency through the conversion of crop residues and agro-industrial by-products into poultry feed resources (Keohavong, 2026a; Keohavong, 2026b). Improved housing, flock management, disease prevention, and veterinary services can further reduce mortality and production losses. Digital technologies, farmer organizations, extension services, market information, and stronger value chains can facilitate knowledge exchange and market participation (Keohavong, 2026a). Regional initiatives involving Lao PDR, Cambodia, and Vietnam also highlight opportunities for cooperation in

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genetics, nutrition, animal health, biosecurity, market development, and institutional capacity building (Nguyen, 2025). Effective interventions, however, must reflect differences in household capacities, resources, production systems, and market conditions (Pal et al., 2024).

Despite the importance of smallholder poultry, evidence on its livelihood contributions and sustainability remains fragmented across the Lower Mekong region (Hett et al., 2023; Birhanu et al., 2023). Existing studies frequently address individual countries, production systems, or specific technical and socioeconomic issues, limiting an integrated understanding of the relationships between poultry production, household livelihoods, and sustainable rural development (Birhanu et al., 2023; Houghton et al., 2025). In particular, the combined influences of nutrition, animal health, genetic resources, environmental conditions, market participation, and institutional support require further synthesis (Birhanu et al., 2023; Hett et al., 2023; Houghton et al., 2025; SNV, 2024). A comparative regional perspective is therefore needed to identify shared constraints, country-specific priorities, research gaps, and opportunities for collaboration (Hett et al., 2023; Houghton et al., 2025). Accordingly, this review synthesizes evidence on smallholder poultry production and rural livelihoods in Lao PDR, Cambodia, Thailand, and Vietnam. It examines production-system characteristics and socioeconomic contributions; the roles of poultry in food security, income, employment, and gender inclusion; the nutritional, genetic, health-related, environmental, economic, and institutional constraints affecting sustainability; and emerging technological, management, and institutional opportunities. Finally, it identifies research gaps and proposes integrated development pathways to strengthen smallholder livelihoods, enhance climate resilience, improve resource-use efficiency, and advance sustainable poultry production across the Lower Mekong region.

2. Smallholder poultry production systems and their socioeconomic contributions in the Lower Mekong region

Smallholder poultry production in the Lower Mekong region encompasses a continuum of traditional backyard, free-range, semi-intensive, and small-scale commercial systems. Traditional households commonly keep small, mixed-age flocks of chickens and ducks under low-input conditions, allowing birds to scavenge around homesteads, rice fields, and surrounding farmland, with supplementary feed derived from household leftovers and locally available agricultural resources. These systems require relatively limited investment and are often integrated with crop cultivation and other livestock activities. Semi-intensive and small-scale commercial systems, in contrast, generally involve larger flocks, more controlled housing, purchased feed, improved or crossbred birds, and stronger market orientation. The distinction is not always absolute, as many households combine scavenging with supplementary feeding and gradually increase flock size in response to market opportunities. Across the Mekong region, these production arrangements reflect differences in household resources, market access, agroecological conditions, and production objectives (USAID Mekong ARCC, 2014; Truong et al., 2021). In Vietnam's Mekong Delta, for example, small-scale commercial native-chicken farms commonly operate between backyard and intensive production, illustrating the diversity of systems within a single region (Truong et al., 2021). The geographical distribution and broad characteristics of these production systems across the four countries are summarized in **Figure 1**, while their principal production features are compared in **Table 1**.

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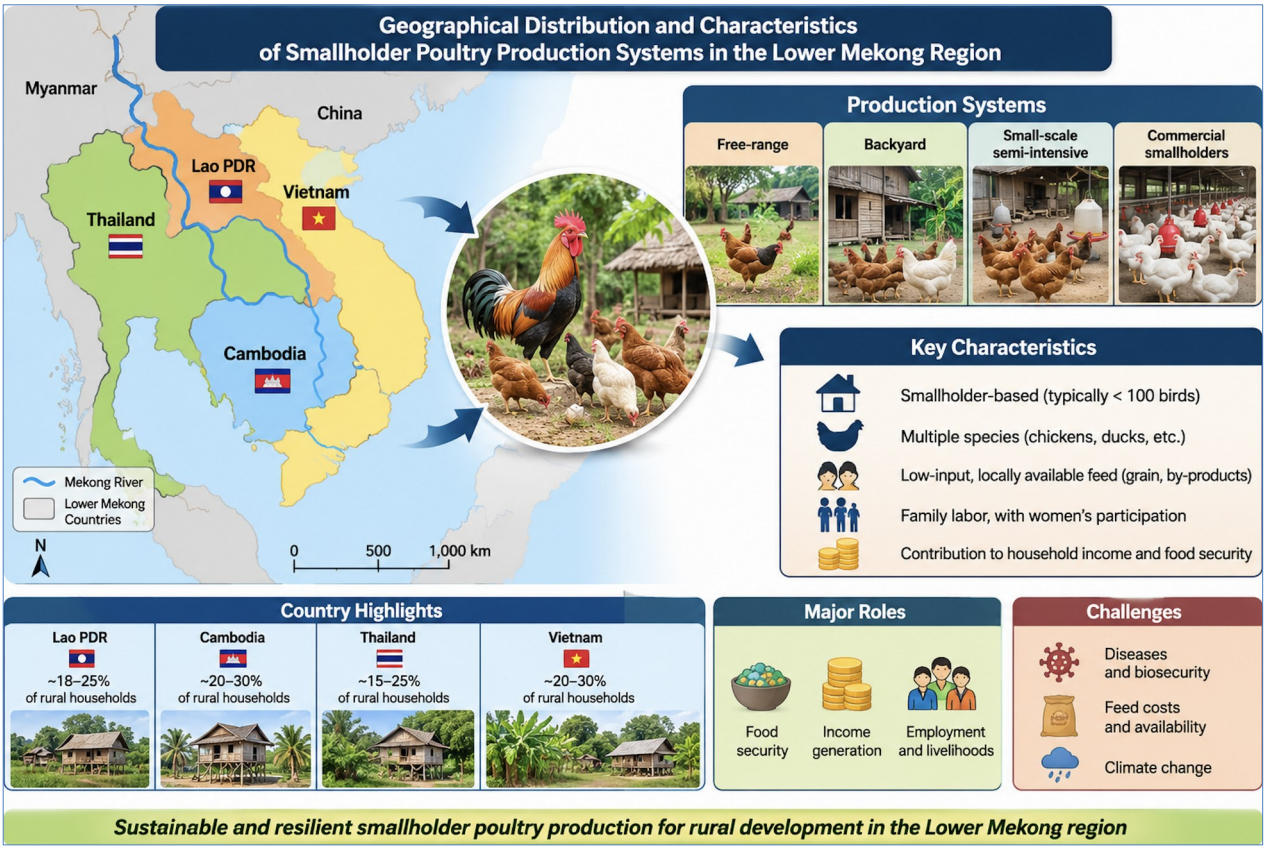


Figure 1. Geographical distribution and characteristics of smallholder poultry production systems in the Lower Mekong region.

Table 1. Characteristics of smallholder poultry production systems in the Lower Mekong region

Country	Main poultry species and production systems	Management and production characteristics	Livelihood and socioeconomic contributions	Major constraints and challenges	Supporting evidence
Lao PDR	Indigenous chickens and ducks are predominant in traditional village systems; small-scale commercial production occurs around urban centres.	Predominantly extensive, backyard, scavenging and low-input systems. Household flocks commonly comprise mixed poultry species.	Household food supply, additional cash income, savings, and an accessible livestock asset for rural households.	Limited commercial feed availability, high feed costs, disease exposure, weak biosecurity, and limited veterinary services and market access.	Wilson (2007); Kryger et al. (2010); USAID Mekong ARCC (2014).
Cambodia	Indigenous chickens and ducks are important in village production; smallholder and semi-intensive systems are also developing.	Traditional free-ranging and backyard management, with emerging improvements in housing, feeding, vaccination and	Household consumption, egg and chicken sales, supplementary income, and livelihood opportunities for women and resource-	Infectious diseases, limited preventive veterinary services, inadequate biosecurity, feed constraints, and	Yitayih et al. (2023); Manilay et al. (2021); Rota et al. (2021); Conan et al. (2013).

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		semi-intensive production.	constrained households.	market and financial limitations.	
Thailand	Indigenous/native chickens, commercial broilers and layers, and smallholder egg production.	Diverse systems, including free-range, semi-intensive and intensive production. Smallholders maintain native chickens and some specialized layer enterprises, often integrated with crop farming.	Household protein supply, supplementary income, local food markets, native breed conservation, and rural entrepreneurship.	Competition with industrial production, disease prevention, feed costs, market fluctuations, and difficulties sustaining smallholder profitability.	Choprakarn and Wongpichet (2007); Heft-Neal et al.(2009); Suwannasri and Promphakping (2022); Charoensook et al. (2021).
Vietnam	Indigenous/local chickens, commercial broilers and layers, and ducks, including traditional and small-scale commercial production.	A mixture of backyard, semi-intensive and intensive systems. Small-scale native chicken farms can operate commercially, with flock sizes varying considerably between households.	Household income, employment, food security, local meat and egg markets, and participation in regional poultry value chains.	High feed and chick costs, disease-related mortality, antimicrobial use, biosecurity limitations, and market and production risks.	Carrique-Mas et al. (2019); Truong et al. (2021); Kryger et al. (2010).

The diversity of poultry species and genetic resources further characterizes smallholder production across the region. Chickens are the principal poultry species in most rural production systems, while ducks are particularly important in areas where poultry keeping is integrated with rice cultivation and wetland-based agriculture. Indigenous and locally adapted chickens are valued for their ability to perform under relatively low-input conditions, their adaptation to local environments, and their cultural and market significance. Cambodia has substantial indigenous chicken diversity, with the Skouy among the locally recognized ecotypes receiving attention for genetic improvement and dual-purpose production (Esatu et al., 2025). In Thailand, important native breeds include Pradu Hang Dum, Leung Hang Kao, Chee, and Dang, while the Pradu Hang Dum has been promoted for improved smallholder production and market opportunities (Loengbudnark et al., 2024). In Lao PDR, household production remains strongly associated with native chickens, supported by locally maintained breeding practices and traditional management (International Labour Organization [ILO], 2024). Vietnam similarly maintains diverse indigenous chicken populations, alongside crossbred and commercial genotypes, while local chickens remain important in small-scale production systems (Nguyen et al., 2026; Truong et al., 2021). These genetic resources provide opportunities to match poultry improvement strategies with farmers' production objectives, local preferences, and environmental conditions.

The socioeconomic contribution of poultry extends beyond the sale of meat and eggs to include household consumption, income diversification, savings, and small-scale enterprise development. For resource-constrained households, poultry can provide relatively accessible animal-source foods and

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generate cash through the sale of live birds, eggs, and breeding stock, helping meet everyday expenses and respond to unexpected financial needs. Evidence from Cambodia indicates that homestead native-chicken production and associated hatchery activities can generate supplementary household income while supporting local food systems and the conservation of indigenous poultry resources (Manilay et al., 2021). Similarly, native-chicken farming in Thailand has demonstrated potential as an income-generating activity, although productivity and economic returns depend substantially on flock management and production conditions (Loengbudnark et al., 2024). However, commercial participation does not necessarily guarantee improved household profitability. In the Mekong Delta of Vietnam, an economic assessment of 203 native-chicken flocks found that feed was the largest production cost and that a substantial proportion of flocks did not generate a positive return when labour costs were excluded from the calculation (Truong et al., 2021). These findings indicate that poultry's contribution to food security and household income varies with production scale, input costs, mortality, management capacity, and market access. The principal livelihood, nutritional, and socioeconomic contributions of smallholder poultry are synthesized in **Table 2**, while their relationships with household resources, production activities, and broader livelihood outcomes are illustrated in **Figure 2**.

Table 2. Contributions of smallholder poultry production to household livelihoods and food security in the Lower Mekong region

Livelihood dimension	Contributions of smallholder poultry production	Benefits to rural households	Supporting evidence
Food security and nutrition	Provides eggs and poultry meat for household consumption, supplying animal-source protein and essential micronutrients.	Improves dietary diversity and access to nutrient-rich foods, particularly in households with limited access to other animal-source foods.	Yitayih et al. (2023); National Institute of Statistics (NIS, 2022)
Household income generation	Generates supplementary income through the sale of live birds, eggs, and poultry meat in local markets.	Provides additional cash to meet daily household expenses and support education, healthcare, and other essential needs.	Yitayih et al. (2023); Truong et al. (2021); Houghton et al. (2025)
Employment and livelihood diversification	Creates opportunities for household-based poultry rearing, small-scale entrepreneurship, and participation in local poultry value chains.	Diversifies household livelihood activities and reduces reliance on crop production or other single income sources.	Yitayih et al. (2023); Truong et al. (2021)
Women's economic participation	Provides opportunities for women to participate in poultry husbandry, flock management, and the marketing of poultry products.	Supports women's involvement in household livestock management and income-generating activities.	Yitayih et al. (2023); Nguyen (2025)
Efficient use of household resources	Enables the utilization of household leftovers, locally available feed resources, and agricultural by-products in traditional backyard systems.	Integrates poultry into mixed farming activities, supports resource utilization, and diversifies agricultural production.	Yitayih et al. (2023); Charoensook et al. (2021); Huy et al. (2023); Manilay et al. (2021)
Household economic resilience	Provides a flexible, small-scale livestock activity that can generate food and supplementary income	Broadens livelihood options and may help households manage economic uncertainty	Pal et al. (2024); Houghton et al. (2025); Yitayih et al. (2023)

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	alongside other agricultural activities.	and livelihood-related risks.	
Contribution to rural agricultural development	Supports widespread household participation in livestock production and local poultry-related economic activities.	Strengthens the role of livestock in smallholder agriculture and contributes to rural economic activity.	National Institute of Statistics (NIS, 2022); Pal et al. (2024); Truong et al. (2021)

Note: The contributions presented in this table reflect the potential and documented roles of smallholder poultry production in household livelihoods. Their magnitude varies according to production systems, household resources, gender roles, market access, and national context. In Cambodia, approximately 75% of agricultural household holdings reported raising poultry, illustrating its widespread participation in smallholder agriculture (NIS, 2022).

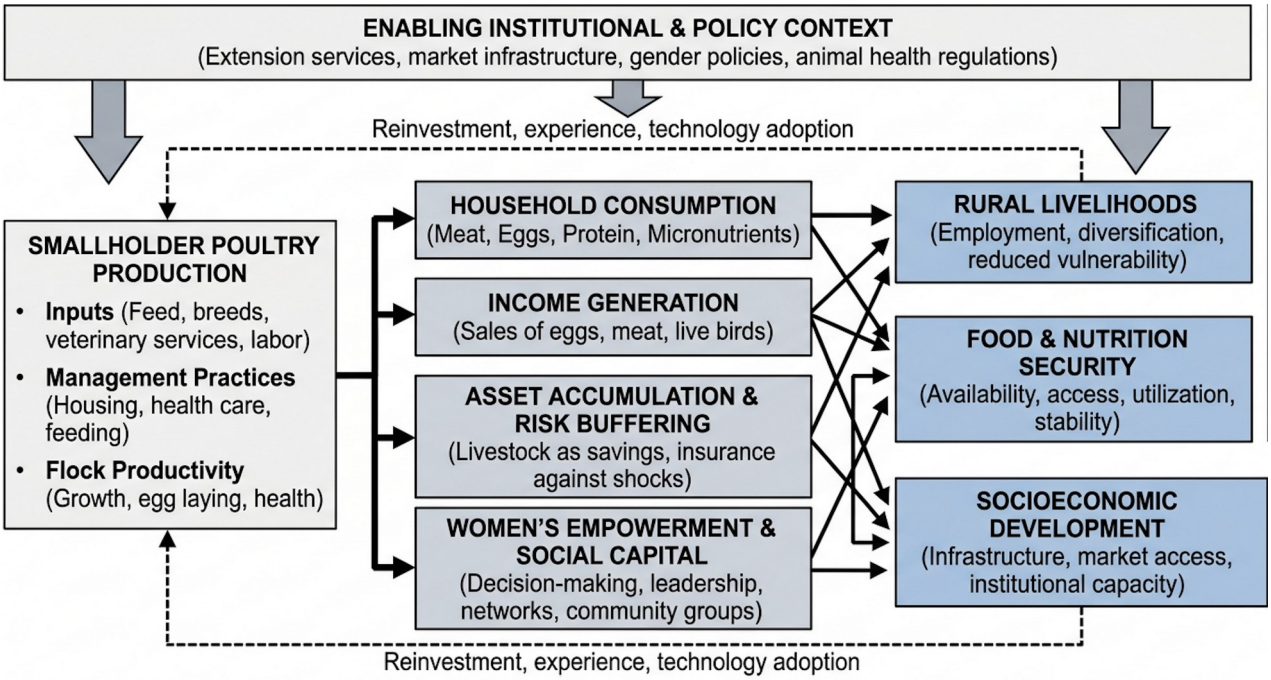


Figure 2. Conceptual framework linking smallholder poultry production with rural livelihoods, food security, and socioeconomic development.

Poultry production also has important social and cultural dimensions, particularly through women's participation, household responsibilities, traditional knowledge, and community relationships. In Lao PDR, women and children undertake much of the work associated with household poultry keeping, while women also participate in activities across the poultry value chain, including rearing, collection, trading, and related services (ILO, 2024). In Vietnam's northern mountainous communities, women raising heritage chickens contribute to household nutrition and income while maintaining indigenous knowledge and locally adapted production practices; the expansion of industrial-scale production may nevertheless affect these livelihoods and the role of smaller-scale female farmers (Nguyen et al., 2026). Native chickens also carry social and cultural value in Thailand and other parts of the region, where they may be associated with traditional practices, local identity, household exchanges, and community-based economic activities (Loengbudnark et al., 2024; USAID Mekong ARCC, 2014). Accordingly, the importance of smallholder poultry should be assessed not only through production volumes and financial returns but also through its contributions to nutrition, women's economic participation, indigenous genetic-resource conservation, and rural social resilience.

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3. Major challenges affecting smallholder poultry production and sustainability

Smallholder poultry production across the Lower Mekong region faces interconnected nutritional, economic, and production-management constraints that limit productivity, profitability, and long-term sustainability. Feed availability, nutritional quality, and production costs are among the most important challenges, particularly in systems that depend on purchased commercial feeds or locally available agricultural by-products with variable nutrient composition. In the Mekong Delta of Vietnam, feed represented a median of 49.5% of total production costs in small-scale commercial chicken flocks, making feed expenditure a major determinant of farm profitability (Truong et al., 2021). In Lao PDR, dependence on imported feed ingredients, increasing input prices, and limited access to balanced rations further constrain smallholder production (International Livestock Research Institute [ILRI], 2025). Inadequate nutrition can compromise growth, reproductive performance, feed conversion efficiency, and disease resistance, while fluctuations in feed prices increase the financial vulnerability of resource-limited households. Animal health constitutes another major constraint, particularly because Newcastle disease, highly pathogenic avian influenza, and other infectious diseases can cause substantial mortality and economic losses. These problems are exacerbated by inadequate vaccination coverage, weak farm-level biosecurity, uncontrolled bird movement, limited diagnostic facilities, and insufficient access to veterinary services. In Cambodia, a recent study found that 51% of surveyed smallholders lacked access to any veterinary service provider, while poultry received comparatively limited veterinary attention despite being the most commonly raised livestock species (McKinley et al., 2026). Similarly, small-scale chicken production in Vietnam has demonstrated substantial flock mortality and economic vulnerability, emphasizing the importance of preventive health management and accessible technical support (Truong et al., 2021).

Environmental and climatic pressures further threaten the resilience of smallholder poultry systems throughout the region. Increasing ambient temperatures, prolonged heat exposure, seasonal water shortages, floods, and droughts can disrupt poultry production through reduced feed intake, impaired growth, lower egg production, increased physiological stress, and elevated mortality. These effects are particularly pronounced in traditional housing systems characterized by inadequate ventilation, limited temperature regulation, insufficient water availability, and exposure to adverse environmental conditions. Climate-related hazards also affect feed availability and household agricultural resources, thereby intensifying competition for land, water, and production inputs. The vulnerability of Lower Mekong livelihoods to climate-related and environmental pressures highlights the importance of strengthening agricultural adaptation and resilience (Pal et al., 2024). Beyond environmental constraints, market accessibility and financial limitations restrict the capacity of smallholder producers to improve production systems and participate in higher-value agricultural markets. High initial investment requirements, limited access to affordable credit, fluctuating farm-gate prices, inadequate transportation, insufficient processing facilities, and weak market information systems can reduce profitability and discourage production expansion. Evidence from Vietnam indicates that approximately 40.9% of assessed chicken flocks generated financial losses when labour costs were excluded, illustrating the economic risks associated with small-scale commercial poultry production (Truong et al., 2021). Comparable structural constraints, including high input costs, inadequate infrastructure, limited capital, and insufficient access to appropriate agricultural technologies, have also been documented in Cambodia (Asian Infrastructure Investment Bank [AIIB], 2023).

Genetic, technical, and institutional limitations represent additional barriers to sustainable poultry development. Although indigenous chickens and ducks are valuable components of smallholder production because of their adaptation to local environments and cultural preferences, uncontrolled breeding, limited access to quality breeding stock, and inadequate genetic improvement programs can restrict productivity and consistency of production. Furthermore, insufficient knowledge of balanced feeding, flock management, disease prevention, housing, and record keeping limits the adoption of improved production practices. These constraints are reinforced by inadequate agricultural extension services, limited farmer training, weak

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institutional coordination, and insufficient investment in smallholder-oriented research and development. Recent poultry-sector consultations in Lao PDR have identified poor genetics, high mortality, rising feed costs, animal diseases, and limited veterinary and extension services as priority constraints requiring coordinated policy responses (ILRI, 2025). Household vulnerability, particularly among resource-poor farmers with limited savings, diversified income sources, and access to agricultural information, further increases exposure to production shocks and market uncertainty. These challenges are not independent; rather, they interact to create cumulative constraints that affect production efficiency, household income, food security, and the capacity to adopt sustainable technologies. As summarized in **Table 3**, addressing these constraints requires integrated interventions combining improved nutrition, preventive animal health management, climate-resilient production, genetic improvement, stronger value chains, accessible financial services, and effective extension systems. Such coordinated approaches are essential for strengthening smallholder resilience and promoting sustainable poultry-based rural livelihoods across the Lower Mekong region.

Table 3. Major constraints affecting smallholder poultry production in the Lower Mekong region

Major constraint	Specific challenges	Implications for poultry production and rural livelihoods	Potential interventions	Supporting evidence
Feed availability, quality, and cost	High prices of commercial feed; dependence on imported ingredients; seasonal availability of local feed resources; imbalanced nutrient composition; limited feed formulation knowledge.	Increased production costs, reduced profit margins, poor growth performance, lower feed efficiency, and greater vulnerability to market fluctuations.	Promote locally available feed ingredients, agricultural by-product utilization, balanced feed formulation, alternative protein sources, and farmer-level feed processing.	Truong et al. (2021); ILRI (2025)
Infectious diseases and animal health	Newcastle disease, highly pathogenic avian influenza, bacterial and parasitic infections, inadequate vaccination, limited disease surveillance, and delayed disease diagnosis.	Increased flock mortality, reduced productivity, financial losses, restricted market access, and increased risks to animal and public health.	Strengthen vaccination programs, veterinary outreach, disease surveillance, early diagnosis, farmer training, and coordinated regional disease-control programs.	Truong et al. (2021); ILRI (2025)
Biosecurity and farm management	Poor housing and sanitation, inadequate isolation of sick birds, uncontrolled bird movement, contact with wild birds, mixed-species rearing, and inappropriate antimicrobial use.	Increased disease transmission, higher mortality, antimicrobial resistance risks, and reduced sustainability of smallholder production.	Implement practical farm-level biosecurity, hygienic housing, controlled animal movement, appropriate antimicrobial stewardship, and improved farm management.	Truong et al. (2021); McKinley et al. (2026)
Genetic resources and breeding	Low productivity of some indigenous breeds, limited access to quality breeding stock, uncontrolled mating, inadequate genetic improvement programs, and limited availability of quality day-old chicks.	Slow growth, variable egg production, inconsistent product quality, and reduced competitiveness of smallholder enterprises.	Improve indigenous breed conservation, selective breeding, community-based breeding programs, and access to quality chicks adapted to local production environments.	ILRI (2025)

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Climate change and environmental pressures	Increasing temperatures, heat stress, floods, droughts, seasonal feed shortages, inadequate ventilation, and poor manure management.	Reduced feed intake, impaired growth and egg production, increased mortality, environmental pollution, and greater livelihood vulnerability.	Promote climate-smart housing, improved ventilation, heat-stress mitigation, water management, climate-resilient feed resources, and sustainable manure utilization.	Pal et al. (2024)
Production costs and financial constraints	High initial investment, increasing feed and chick prices, limited access to agricultural credit, fluctuating input prices, and inadequate financial management.	Reduced profitability, limited investment in improved technologies, production interruptions, and increased economic vulnerability.	Improve access to affordable credit, cooperative purchasing, financial literacy, farm budgeting, and risk-management mechanisms.	Truong et al. (2021); ILRI (2025)
Market access and value-chain limitations	Poor rural infrastructure, limited market information, unstable farm-gate prices, dependence on intermediaries, inadequate processing facilities, and inconsistent product quality.	Reduced bargaining power, post-production losses, unstable household income, and limited incentives for production expansion.	Strengthen farmer cooperatives, market information systems, local processing, product quality standards, and market linkages.	Truong et al. (2021)
Knowledge, extension, and institutional support	Limited access to veterinary and extension services, inadequate technical training, weak farmer organizations, poor record keeping, and limited access to appropriate technologies.	Inefficient production practices, delayed disease response, poor resource management, and slow adoption of sustainable innovations.	Strengthen agricultural extension, community-based animal health services, farmer field schools, digital advisory services, and regional research collaboration.	McKinley et al. (2026); ILRI (2025)

4. Technological innovations and sustainable development pathways

Technological innovation in feed resources and nutritional management offers important opportunities to improve the productivity, profitability, and environmental sustainability of smallholder poultry systems in the Lower Mekong region. Alternative feed ingredients, including locally available agricultural by-products, rice bran, cassava residues, palm kernel cake, copra meal, insect-derived protein, microalgae, and single-cell protein, can reduce dependence on conventional feed ingredients such as soybean meal and fishmeal. Their integration into circular agricultural systems can connect agricultural by-product valorization, alternative feed production, and resource recycling, providing a pathway for more sustainable poultry production (**Figure 3**). However, their successful utilization requires appropriate processing, nutrient characterization, digestibility assessment, and balanced formulation to ensure consistent nutritional quality and feed safety. Biotechnology-based approaches, including microbial fermentation, precision fermentation, enzyme supplementation, and microbial protein production, can further enhance the nutritional value and utilization of alternative feed resources (Keohavong, 2026a). Improved nutritional management through phase feeding, digestible amino acid balancing, reduced-crude-protein diets, and precision feeding can enhance feed conversion efficiency while reducing nitrogen and phosphorus excretion. The integration of digital formulation tools and nutrient requirement models may help optimize dietary composition according to poultry species, age, production stage, and locally available ingredients. Furthermore, life cycle assessment (LCA) provides an important framework for evaluating the environmental implications of feed production, ingredient sourcing, transportation, nutrient utilization, and poultry production, allowing nutritional

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interventions to be assessed in terms of both productive and environmental performance (Keohavong, 2026b).

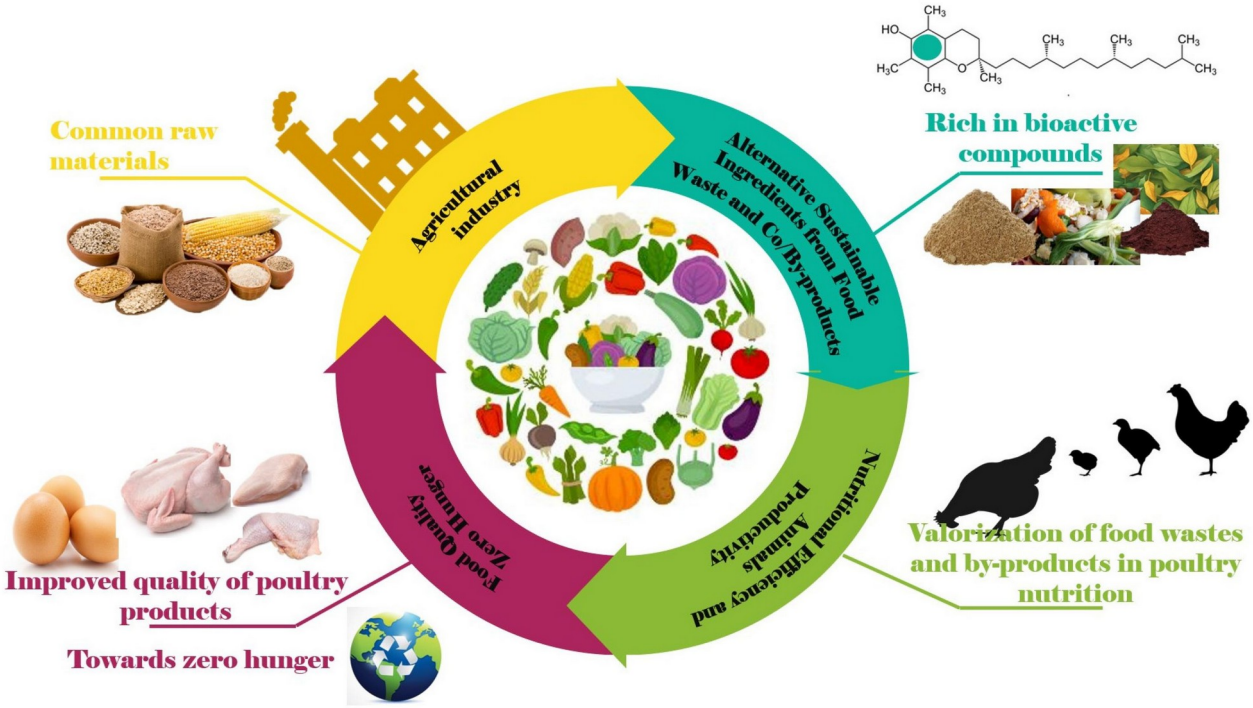


Figure 3. Integrated pathways for sustainable poultry production through circular agriculture and alternative feed resource utilization. *Source: Adapted from Vlaicu et al. (2024), Agriculture, 14(10), Article 1811 (https://doi.org/10.3390/agriculture14101811). Adapted under the Creative Commons Attribution 4.0 International (CC BY 4.0) licence.*

Circular agriculture provides another important pathway for improving resource efficiency and strengthening the economic resilience of smallholder poultry enterprises. Integrating poultry production with crop farming and agro-industrial activities facilitates the conversion of agricultural residues and processing by-products into valuable feed ingredients, while poultry manure can be recycled through composting, anaerobic digestion, and organic fertilizer production. Appropriately managed insect-based bioconversion systems can also transform selected organic waste streams into protein-rich feed ingredients, creating opportunities to connect waste management, feed production, and agricultural value chains (Keohavong, 2026a). Nevertheless, feed safety, microbial contamination, heavy metals, and appropriate processing standards must be carefully considered. Improvements in indigenous poultry genetics and breeding are equally important for sustainable development. Participatory breeding programs, selective breeding, conservation of locally adapted genetic resources, and community-based hatchery systems can improve growth, reproductive performance, survival, and disease resilience while maintaining traits valued by rural households. Recent regional initiatives under the Asian Chicken Genetic Gains program demonstrate opportunities to improve chicken productivity through locally adapted breeds, participatory breeding, and stronger production systems in Cambodia, Lao PDR, and Vietnam (International Livestock Research Institute [ILRI], 2026). At farm level, appropriate housing, adequate ventilation, suitable stocking density, clean drinking water, routine vaccination, and practical biosecurity measures are essential for reducing disease transmission and production losses. However, evidence from a cluster-randomised trial in Cambodian backyard poultry flocks indicates that the implementation of basic biosecurity measures alone did not significantly reduce poultry mortality, highlighting the need for integrated disease prevention strategies supported by appropriate veterinary services and context-specific management practices (Conan et al.,

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2013). Strengthening veterinary services and farmer training is also necessary to facilitate the adoption of these technologies (MacPhillamy et al., 2022).

Digital technologies, biotechnology, and artificial intelligence (AI) offer additional opportunities to improve the efficiency and resilience of smallholder poultry production. Machine-learning models, digital decision-support tools, and predictive analytics can support feed formulation, flock monitoring, disease surveillance, and production management, although their application requires affordable infrastructure, reliable data, and appropriate digital skills (Keohavong, 2026a). Climate-smart practices, including improved ventilation, shaded housing, appropriate stocking densities, heat-stress mitigation, and reliable water provision, are also important for maintaining productivity under increasingly variable climatic conditions. Furthermore, improved manure management through composting, nutrient recovery, and biogas production can reduce environmental pollution while creating opportunities to recycle nutrients within integrated crop-livestock systems. Evaluating these interventions through life cycle assessment and techno-economic analysis can help identify approaches that are both environmentally beneficial and financially feasible for smallholder farmers (Keohavong, 2026b; Pal et al., 2024). Collectively, these technological and management interventions provide complementary pathways for improving production efficiency, strengthening climate resilience, and reducing the environmental footprint of smallholder poultry systems in the Lower Mekong region (Table 4).

Table 4. Sustainable technologies and innovations for smallholder poultry development in the Lower Mekong region

Sustainability area	Recommended technologies and innovations	Expected benefits for poultry production and rural livelihoods	Key implementation requirements	Supporting literature
Alternative feed ingredients and nutritional biotechnology	Incorporation of insect-derived protein (black soldier fly larvae), single-cell protein, microbial biomass, microalgae, precision-fermentation products, fermented feed, exogenous enzymes, probiotics, and locally available agro-industrial by-products.	Reduce dependence on conventional soybean meal and fishmeal, improve nutrient utilization, support growth and egg production, enhance intestinal health, and reduce feed costs and environmental pressures.	Local feed-resource assessment, nutrient composition and digestibility evaluation, amino acid balancing, feed safety assessment, and cost–benefit analysis.	Keohavong (2026a); Osei-Akoto et al. (2026); Guo et al. (2026); Wongtangtintharn et al. (2025)
Precision nutrition and feed management	Phase feeding, low-crude-protein diets balanced with essential amino acids, precision feed formulation, enzyme supplementation, nutrient requirement modeling, and sensor-supported feeding management.	Improve feed conversion efficiency, reduce nitrogen and phosphorus excretion, minimize nutrient wastage, lower feed-related greenhouse gas emissions, and improve production profitability.	Species- and age-specific nutrient requirements, reliable feed composition data, trained nutritionists, affordable formulation tools, and appropriate environmental performance indicators.	Keohavong (2026b); Keohavong (2026a); Osei-Akoto et al. (2026); Guo et al. (2026)
Improved animal health and disease prevention	Community-based vaccination, particularly against Newcastle disease; routine health	Reduce disease incidence and flock mortality, improve production stability,	Affordable vaccines, reliable vaccine delivery, trained veterinary personnel,	MacPhillamy et al. (2022); Guo et al. (2026); ILRI (2026)

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	monitoring; farm-level biosecurity; disease surveillance; improved hygiene; and accessible veterinary and para-veterinary services.	minimize economic losses, and strengthen household food security.	cold-chain facilities, and farmer participation.	
Genetic improvement and breeding technologies	Participatory indigenous chicken breeding, selective breeding, access to locally adapted improved genotypes, improved chick production, and community-based multiplication and distribution systems.	Improve growth performance, survival, egg production, adaptability, and the economic value of indigenous poultry while conserving locally important genetic resources.	Farmer-preferred breeding objectives, performance recording, hatchery development, genetic resource conservation, and public–private partnerships.	ILRI (2024, 2026); Guo et al. (2026)
Climate-smart housing and environmental management	Improved ventilation, shade provision, appropriate stocking density, heat-stress mitigation, reliable drinking-water systems, flood-resilient housing, and climate-adapted farm management.	Reduce heat stress and mortality, maintain feed intake and production performance, improve animal welfare, and strengthen resilience to climatic extremes.	Locally appropriate housing designs, affordable construction materials, climate information, water management, and farmer training.	Pal et al. (2024); Wongtangtintharn et al. (2025); Guo et al. (2026); Keohavong (2026b)
Circular agriculture and waste valorization	Integration of poultry with crop production; conversion of agricultural residues into feed ingredients; microbial fermentation; insect-based waste bioconversion; poultry manure composting; organic fertilizer production; and biogas generation.	Improve resource-use efficiency, reduce waste-management costs, recycle nutrients, decrease dependence on external inputs, and generate additional farm income.	Appropriate waste treatment, feed and fertilizer safety assessment, nutrient management, technical knowledge, and local processing facilities.	Keohavong (2026a); Keohavong (2026b); Osei-Akoto et al. (2026); Melati et al. (2026)
Digital technologies and biotechnology integration	Integration of artificial intelligence, machine learning, multi-omics, predictive modeling, digital twins, mobile-based veterinary advisory services, electronic farm records, and digital decision-support systems for feed formulation and production monitoring.	Improve feed formulation, optimize alternative protein development, support early disease detection, improve production decisions, and enhance resource efficiency and technological innovation.	Affordable digital infrastructure, internet connectivity, farmer digital literacy, reliable datasets, analytical capacity, and locally relevant applications.	Keohavong (2026a); Keohavong (2026b); Wongtangtintharn et al. (2025); Osei-Akoto et al. (2026)
Life cycle assessment and environmental decision-support tools	Application of LCA, techno-economic assessment (TEA), environmental footprint analysis, nutrient-flow assessment, and	Identify environmental hotspots, quantify greenhouse gas emissions, assess land and water	Standardized system boundaries, appropriate functional units, reliable regional datasets, transparent assumptions, and	Keohavong (2026b); Keohavong (2026a); Pal et al. (2024); Osei-Akoto et al. (2026)

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	integrated productivity–profitability–environmental evaluation of poultry feeding systems.	requirements, evaluate nutrient losses, and identify economically feasible sustainability interventions.	alignment with ISO 14040/14044 and FAO LEAP guidelines.	
Market development and value-chain innovation	Farmer cooperatives, collective input purchasing, improved poultry collection systems, local processing, product quality assurance, market information platforms, and development of indigenous chicken and egg value chains.	Strengthen market participation, improve bargaining power, reduce transaction costs, increase product value, and stabilize household income.	Market infrastructure, access to finance, producer organizations, appropriate quality standards, and collaboration with private-sector stakeholders.	ILRI (2024, 2026); Truong et al. (2021)
Extension, institutional support, and capacity development	Farmer field schools, participatory training, community-based animal health services, demonstration farms, public–private partnerships, regional research networks, and gender-responsive extension programs.	Improve technical knowledge, accelerate adoption of sustainable practices, strengthen institutional capacity, and enhance the participation of women and resource-limited households.	Government commitment, qualified extension personnel, sustained funding, inclusive training, and coordination among research institutions and development partners.	MacPhillamy et al. (2022); ILRI (2026); Pal et al. (2024)

5. Regional perspectives, policy development, and cross-country collaboration

Smallholder poultry production across Lao PDR, Cambodia, Thailand, and Vietnam reflects differences in production intensity, market development, institutional capacity, and access to veterinary and technical services. In Lao PDR and Cambodia, village-based and smallholder poultry systems remain important for household food security, income generation, and rural livelihoods, although their development is constrained by limited access to improved genetics, quality feed, animal health services, and reliable markets. Evidence from Cambodia indicates considerable diversity in smallholder poultry production, with indigenous chickens playing an important role in household production systems (Yitayih et al., 2023). Similarly, the development of Lao PDR's poultry sector has identified genetic improvement, feed availability, vaccination, veterinary services, and market development as important national priorities (Alemayehu et al., 2026; International Livestock Research Institute [ILRI], 2025). Thailand and Vietnam have more developed commercial poultry sectors, supported by relatively established input supply networks, processing facilities, veterinary infrastructure, and market-oriented production systems (Truong et al., 2021; Wongtangtintharn et al., 2025). Nevertheless, small-scale and traditional poultry production continues to coexist with commercial operations, creating diverse opportunities and challenges for sector development. In Cambodia, poultry remains one of the most commonly raised livestock species among smallholder households, yet access to veterinary services is limited (McKinley et al., 2026). These differences suggest that regional poultry development strategies should be adapted to national production conditions while recognizing shared priorities, including improved productivity, disease prevention, market access, and environmental sustainability (Pal et al., 2024; ILRI, 2026).

Cross-border livestock trade and regional poultry value chains also influence the sustainability and competitiveness of smallholder production. The movement of live birds, poultry products, feed ingredients,

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breeding stock, and other production inputs across national borders creates opportunities to expand markets, strengthen supply networks, and improve access to technologies. However, informal trade and the movement of animals through poorly monitored marketing channels can increase the risk of transboundary disease transmission, particularly where animal identification, movement control, and veterinary inspection are inadequate (Asian Development Bank [ADB], 2024; Food and Agriculture Organization of the United Nations [FAO], 2023). Strengthening veterinary infrastructure, animal identification, movement documentation, border inspection, vaccination programs, and coordinated disease surveillance is therefore important for reducing animal health risks while facilitating safer regional trade. Evidence from Cambodian backyard poultry systems also demonstrates that disease prevention requires context-specific interventions, as basic biosecurity measures alone may not be sufficient to reduce poultry mortality (Conan et al., 2013). Regional cooperation through the Association of Southeast Asian Nations (ASEAN) and relevant animal health networks can support information exchange, harmonized surveillance approaches, and coordinated responses to priority transboundary diseases. In particular, ASEAN's Post-2020 Avian Influenza Control Framework and its regional veterinary epidemiology capacity-development framework provide mechanisms for strengthening preparedness, surveillance, and coordinated responses to poultry and zoonotic disease threats (FAO, 2023). These measures are particularly important for poultry diseases that can spread rapidly across production and trading networks and affect both smallholder livelihoods and commercial supply chains.

Regional research collaboration and technology transfer provide further opportunities to address common production constraints. Joint research involving universities, government agencies, international research organizations, and the private sector can facilitate the evaluation of locally available feed resources, improved poultry genetics, vaccination strategies, biosecurity practices, and climate-resilient production technologies under different farming conditions. Regional initiatives such as the Asian Chicken Genetic Gains (AsCGG) program illustrate the potential of collaborative approaches to improve poultry productivity and strengthen smallholder production systems in Southeast Asia, including Cambodia, Lao PDR, and Vietnam. The initiative brings together international and national research institutions and private-sector stakeholders to improve access to locally adapted and productive chicken breeds and associated technologies (Alemayehu et al., 2026; ILRI, 2026). At the national level, poultry development strategies should establish clear priorities for genetic improvement, feed resource development, veterinary service delivery, farmer training, market infrastructure, and environmental management. The development of Lao PDR's National Poultry Development Strategy 2026–2035 provides an example of national policy efforts to establish a coordinated framework for poultry-sector development (ILRI, 2025). Institutional support can also be strengthened through farmer organizations, producer cooperatives, public-private partnerships, and inclusive value-chain arrangements that connect smallholders with input suppliers, veterinary providers, processors, and markets. Strengthening farmer knowledge and animal-health practices is particularly important in Cambodia and Lao PDR, where research has identified opportunities to improve livestock health, biosecurity, and management through farmer capacity development (MacPhillamy et al., 2022). Coordinated national policies and cross-country collaboration can consequently help translate technological advances into practical improvements in productivity, resilience, and livelihood outcomes across the Lower Mekong region.

6. Research gaps and future development priorities

Research on smallholder poultry production in the Lower Mekong region has generated valuable insights; however, evidence remains fragmented across disciplines and countries. Existing studies often emphasize individual production or economic indicators, with limited integration of productivity, household livelihoods, nutrition, gender, and environmental sustainability. Although baseline assessments in Cambodia and Vietnam provide useful information, comparable longitudinal evidence across Lao PDR, Cambodia, Thailand, and Vietnam remains insufficient (Yitayih et al., 2023). Further research should quantify poultry's contributions to household income, food security, dietary diversity, employment, and resilience. Harmonized

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cross-country surveys and interdisciplinary research frameworks are needed to support regional comparisons. This priority is consistent with findings from a Southeast Asian systematic review highlighting limited integration of economic, social, and environmental dimensions in local poultry sustainability assessments (Ridwan et al., 2026).

Future research should examine interactions among climate resilience, feed systems, genetics, and animal health. Priorities include evaluating the nutritional quality, safety, digestibility, and economic feasibility of locally available feed resources and alternative proteins, alongside research on heat stress, water availability, disease dynamics, housing, and locally adapted poultry genotypes. Digital technologies and artificial intelligence also warrant evaluation for their affordability, accessibility, and measurable benefits under smallholder conditions. Participatory on-farm studies and regional initiatives, including the Asian Chicken Genetic Gains programme, can support farmer-preferred genetic improvement and appropriate technology delivery.

Equitable development requires greater attention to women's and young people's participation, access to productive resources, training, finance, veterinary services, and markets. Strengthening farmer organizations, extension services, veterinary infrastructure, disease surveillance, and cross-border research collaboration is equally important. The major research gaps and corresponding priority actions are summarized in **Table 5**. Progress should ultimately be assessed using integrated indicators of productivity, profitability, household welfare, gender inclusion, animal health, climate resilience, and environmental sustainability.

Table 5. Research gaps and priority actions for sustainable smallholder poultry development in the Lower Mekong region

Research area	Key research gaps	Priority actions	Expected outcomes
Production systems and regional evidence	Fragmented evidence and limited comparable data across Lao PDR, Cambodia, Thailand, and Vietnam; insufficient longitudinal studies of productivity and livelihoods.	Conduct harmonized, cross-country surveys and longitudinal studies covering production performance, household income, food security, and resilience.	More reliable regional evidence to guide context-specific policies and investment.
Feed resources and nutritional management	Limited information on the nutritional quality, safety, digestibility, availability, and economic feasibility of locally available feed resources.	Evaluate locally available feed ingredients, agro-industrial by-products, insect-based proteins, and precision-feeding strategies through laboratory and on-farm trials.	Lower feed costs, improved nutrient utilization, and more resource-efficient poultry production.
Animal health and climate resilience	Inadequate disease surveillance, limited veterinary access, and insufficient evidence on interactions among heat stress, disease risks, housing, and productivity.	Strengthen participatory disease surveillance, preventive health management, biosecurity, vaccination, and climate-adapted housing and management practices.	Reduced disease-related losses and improved flock health and resilience.
Genetic resources and breeding	Limited characterization, conservation, and performance evaluation of indigenous poultry genetic resources under smallholder conditions.	Characterize local breeds and ecotypes and develop participatory breeding and selection programs that balance productivity, adaptability, and	Improved locally adapted poultry populations and preservation of valuable genetic

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		genetic conservation.	resources.
Technology adoption and environmental sustainability	Limited evidence on the affordability, accessibility, and long-term impacts of digital technologies, circular resource use, and environmental innovations in smallholder systems.	Assess technology adoption barriers and conduct on-farm evaluations of digital advisory services, manure recycling, circular feed systems, and life cycle and economic performance.	More accessible innovations, improved resource efficiency, and reduced environmental impacts.
Gender, livelihoods, and social inclusion	Insufficient understanding of gender-differentiated benefits, labor contributions, decision-making, and access to productive resources and services.	Integrate gender-sensitive and socioeconomic assessments into poultry research and development; improve women's and young people's access to training, finance, markets, and veterinary services.	More equitable participation, stronger household livelihoods, and inclusive rural development.
Institutions, markets, and regional collaboration	Weak coordination among research institutions, extension services, producer organizations, private-sector actors, and regional animal-health networks.	Strengthen extension systems, farmer organizations, public–private partnerships, market linkages, and cross-border research and disease-surveillance collaboration.	Stronger institutional capacity, improved market participation, and coordinated regional development.

6. Conclusion

Smallholder poultry production remains an important component of rural livelihoods across Lao PDR, Cambodia, Thailand, and Vietnam, contributing to household nutrition, supplementary income, employment, and livelihood diversification. Nevertheless, its potential is constrained by interconnected challenges involving feed availability and costs, animal diseases, limited veterinary services, genetic improvement, climate variability, financial limitations, and market access. Addressing these constraints requires integrated approaches that extend beyond increasing production to strengthening household profitability, animal health, environmental performance, and social inclusion. Locally appropriate feed innovations, improved indigenous poultry genetics, preventive health management, climate-smart housing, circular resource utilization, and accessible digital technologies offer promising development pathways. However, their effectiveness depends on affordability, farmer participation, institutional capacity, and adaptation to national and local production conditions. Greater investment in extension services, veterinary infrastructure, gender-responsive development, research capacity, and cross-border collaboration is therefore essential. Coordinated regional and national policies can help transform smallholder poultry systems into more productive, resilient, and inclusive contributors to sustainable rural development throughout the Lower Mekong region.

Animal Ethics

No live animals were used, handled, or experimented on in this review. Therefore, ethical approval from an institutional animal care and use committee was not required.

Permits

No permits for animal collection, transport, or access were required because this review was based exclusively on previously published literature and publicly available information.

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Declarations

Competing interests

The authors declare that they have no competing financial or non-financial interests that could have influenced the work reported in this manuscript.

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