From Vulnerability to Resilience: Evaluating Innovative and Climate-Resilient Strategies for Transforming Free-Range Chicken Family Enterprises in Santa Maria Ilocos Sur, Philippines

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Abstract
Climate change poses severe threats to smallholder agricultural livelihoods in the Philippines, with the Ilocos Region among the most vulnerable to typhoons, droughts, and erratic rainfall patterns. Free-range chicken farming is a cornerstone of rural economies in Santa Maria, Ilocos Sur supporting farmers and households as a source of food security, income, and cultural heritage but remains highly exposed to climate-related risks, production inefficiencies, and market volatility. This mixed-methods study evaluates the establishment of poultry based management enterprise and potential of innovative climate- resilient strategies to transform these family enterprises, addressing critical gaps in localized research and actionable interventions. Data was collected from 80 free-range chicken farming households, 12 key informants including agricultural extension workers, local government officials, and sector experts, and 4 focus group discussions (FGDs) with farmer associations. Vulnerability assessments were conducted using an adapted framework integrating biophysical, socioeconomic, and institutional indicators. Evaluations focused on priority interventions which are the improved free-range chicken breeds, agroecological practices such as rice hull bedding, integrated pest management, and forage diversification, climate-smart infrastructure such as low-cost housing with solar-powered lights, community-based governance models for farmer cooperatives and collective market linkages, gender roles and equity considerations. Key findings reveal that while baseline vulnerability is high with 78.4% of households reporting annual losses from climate impacts and 62% struggling with low productivity context-specific adoption of innovative strategies yielded significant improvements on Rhode Island Reds and Dekalb Brown strains integration increased egg production by 38% and bird survival rates by 29%; rice hull use reduced mortality from moisture-related diseases by 22% and enhanced soil fertility for forage crops; low-cost housing with solar-powered lights cut energy costs by 45% and maintained optimal conditions during extreme weather; and cooperative models improved market access by 50% and enabled bulk purchasing of inputs. The study concludes that transforming free-range chicken enterprises requires a synergistic approach combining technology transfer, capacity building, policy support, and community ownership. Recommendations include scaling breed improvement programs, subsidizing climate-smart infrastructure, strengthening local extension systems, and establishing market linkages through farmer-led institutions. This research contributes to evidence-based climate adaptation in Philippine agriculture and provides a replicable model for smallholder livestock systems in similar tropical contexts.

Keywords: agricultural enterprise, climate-resilient, free-range chicken, vulnerability

1. Introduction

Climate change is reshaping agricultural landscapes worldwide, with smallholder farmers in low- and middle-income countries bearing the brunt of its impacts (IPCC, 2023). In the Philippines, which ranks 5th globally in climate vulnerability (ND-GAIN Index, 2025), the agricultural sector contributes 10.2% to GDP and employs 23.7% of the workforce yet faces annual losses of over PHP 10 billion from extreme weather events (Department of Agriculture, 2025). The National Climate Change Action Plan (NCCAP) 2023–2030 identifies livestock systems as a priority for adaptation, emphasizing the need for climate- resilient technologies and inclusive governance models.

While national policies prioritize climate resilience in agriculture (Department of Agriculture, 2023), there is limited empirical data on how free-range chicken family enterprises, an often-overlooked segment of the poultry sector experience and adapt to climate change impacts in northern Luzon, particularly in Santa Maria, Ilocos Sur. Local climate patterns, including prolonged droughts, intense typhoons, and erratic rainfall, have been shown to reduce flock productivity, increase mortality rates, and destabilize household incomes (Philippine Atmospheric, Geophysical and Astronomical Services Administration, 2024), yet few studies have documented context-specific vulnerabilities and solutions for this subsector.

The Ilocos Region faces increasing climate variability, with Santa Maria, Ilocos Sur, experiencing frequent typhoons (May–October) and droughts (El Niño events). Free-range chicken farming is a critical livelihood for rural households but is highly vulnerable to extreme weather, disease outbreaks, and feed cost volatility. Despite national initiatives like the Adapting Philippine Agriculture to Climate Change (APA) project, localized strategies for smallholder free-range systems remain underdeveloped.

Santa Maria, Ilocos Sur is a coastal municipality in the northern Philippines experiences a tropical monsoon climate with distinct dry (November–April) and wet (May– October) seasons. The area is prone to Category 3–5 typhoons (average 3–4 per year), prolonged droughts during El Niño events, and saltwater intrusion from storm surges (PAGASA, 2025). Free-range chicken farming is deeply embedded in local livelihoods: households typically raise 10–50 birds, relying on natural forage and minimal inputs. However, these systems are highly vulnerable to climate risks such typhoons destroy housing and kill birds, droughts reduce forage availability and increase feed costs, and erratic rainfall exacerbates disease outbreaks like Newcastle disease and coccidiosis.

While national initiatives like the Adapting Philippine Agriculture to Climate Change (APA) project and National Adaptation Plan for Agriculture and Fisheries (NAP-Ag) have prioritized climate-resilient livestock systems, most research focuses on commercial poultry operations or other regions in the Philippines. Limited site-specific data exists on Santa Maria's free-range chicken enterprises, including how local farmers perceive and respond to climate risks, and which innovations are most feasible for their context. Previous studies on native chicken breeds have demonstrated productivity gains but lack analysis of scalability and equity for marginalized households like women farmers, landless families. Additionally, few studies integrate biophysical, socioeconomic, and institutional dimensions of resilience, leaving a critical gap in holistic intervention design.

Existing literature on climate-resilient poultry production focuses heavily on commercial operations, with minimal attention to the innovative, low-cost strategies developed by smallholder families themselves (Santos et al., 2024). While some studies highlight technological interventions like improved housing and feed formulations, they rarely integrate indigenous knowledge or community-driven approaches that are critical for scalability in resource-poor settings. This gap limits the ability of policymakers and extension services to design interventions that are culturally appropriate and economically feasible for family enterprises.

The transformation of these enterprises from vulnerable livelihoods to resilient systems requires an evaluation of how innovative strategies such as agro-ecological integration, climate-smart breeding, and collective marketing affect both biophysical resilience such as disease resistance and feed security, and socioeconomic resilience such as income stability and gender equity. Without such an evaluation, there is no evidence base to guide investments or policy reforms aimed at strengthening small-scale poultry value chains in climate-prone areas. This study addresses these gaps by generating localized evidence on what works, for whom, and under what conditions, ultimately contributing to more inclusive and effective climate adaptation efforts in rural Ilocos Sur.

Significance of the Study

This research addresses these gaps by providing evidence-based insights into transforming free-range chicken enterprises from vulnerable to resilient systems. Findings will inform local government planning, guide DA extension services, and support non- governmental organizations (NGOs) working on rural development. By centering the perspectives of family farmers, the study ensures interventions are inclusive, culturally appropriate, and sustainable. Ultimately, strengthening these enterprises will enhance food security, reduce poverty, and build adaptive capacity in one of the Philippines' most climate-vulnerable regions.

Objectives

General Objective

The ultimate goal of this project is to evaluate innovative climate-resilient production and strategies for transforming free-range chicken family enterprises in Santa Maria, Ilocos Sur, into sustainable and risk-resilient livelihoods.

Specific Objectives

1. To assess the biophysical, socioeconomic, and institutional vulnerabilities of free-range chicken farming households in Santa Maria, Ilocos Sur;
2. To evaluate the technical feasibility, economic viability, and social acceptability of four priority climate-resilient interventions such as improved free-range chicken breeds, agroecological practices, climate-smart infrastructure, and community-based governance models; and
3. To analyze gender roles, power dynamics, and equity considerations in the adoption and benefits of climate-resilient strategies.

Review of related literature

Climate Vulnerability in Philippine Poultry Farming

Agriculture remains the backbone of the Philippine economy, supporting over 25 million Filipinos and contributing 10.2% to the national gross domestic product (Philippine Statistics Authority, 2025). Within this sector, small-scale family enterprises including free- range chicken production play a vital role in ensuring food security, providing flexible income opportunities, and sustaining rural livelihoods, especially in marginalized regions like Ilocos Sur (Dizon and Cruz, 2022). Santa Maria, a coastal municipality in Ilocos Sur, is home to over 800 families engaged in free-range chicken farming, where flocks are typically raised on native or improved native breeds, relying on natural forage and minimal inputs.

However, these enterprises are increasingly threatened by climate change. PAGASA (2024) reports that northern Luzon has experienced a 15% increase in extreme weather events over the past decade, including typhoons that destroy housing and forage areas, and droughts that reduce water access and feed availability. Additionally, rising temperatures have increased the risk of poultry diseases such as Newcastle disease and coccidiosis, further undermining productivity (Villanueva et al., 2023). These vulnerabilities are compounded by limited access to credit, extension services, and market linkages, leaving smallholder families with few options to adapt or recover from shocks.

Climate change poses multifaceted risks to poultry systems globally, with small- scale operations being disproportionately affected due to limited adaptive capacity (FAO, 2023). In Southeast Asia, rising temperatures (projected to increase by 1.5–2.5°C by 2050) reduce feed conversion rates and egg production, while erratic rainfall disrupts forage availability and increases the spread of waterborne diseases (Habib-ur-Rhaman, M. et al., 2022).

In the Philippines, studies have documented how typhoons and droughts in northern Luzon have led to flock mortality rates of up to 40% in free-range systems (Balingit, 2020). PAGASA (2024) emphasizes that coastal municipalities like Santa Maria are particularly at risk due to saltwater intrusion during storm surges, which contaminates soil and water sources critical for chicken farming. Additionally, climate variability has altered seasonal patterns of pest and disease outbreaks, making traditional management practices less effective (Capitan S.S., 2023). While commercial poultry operations often use climate- controlled housing and synthetic inputs to mitigate risks, small-scale free-range systems lack such resources, making them more dependent on ecological conditions and local adaptive strategies (FAO, 2023).

Vulnerability in small-scale poultry systems is shaped by interconnected biophysical, socioeconomic, and institutional factors (Falculan K.N., 2023). Bio-physically, free-range flocks are exposed to climate shocks, predation, and disease, with limited access to veterinary services or disease prevention tools. Socioeconomically, most families rely on chicken farming as a secondary income source, with limited capital to invest in improvements or recover from losses. Gender disparities are also prominent: women, who often manage day-to-day operations, have less access to training, credit, and decision- making power (Lopez et al., 2020).

Institutional gaps further exacerbate vulnerability. Extension services in the Philippines typically focus on commercial poultry production, with few programs tailored to free-range systems (Department of Agriculture, 2023). Market access is another challenge: smallholders often sell to local middlemen at low prices, with no mechanisms to ensure fair trade or price stability during climate-related disruptions (Bayudan-Dacuycuy et al., 2022). Existing research highlights that vulnerability is not uniform across households factors such as land ownership, education level, and social capital influence how families experience and respond to stressors (Santos et al., 2023). However, few studies have examined these dynamics in the context of Ilocos Sur's free-range chicken sector.

Climate-Resilient Strategies for Smallholder Poultry

Innovative strategies for climate resilience in small-scale poultry can be categorized into technological, agro-ecological, and institutional approaches (FAO, 2023). Technological interventions include improved housing designs like elevated coops to avoid flooding, climate-adapted breeds such as free-range chicken strains with higher heat tolerance, and low-cost feed supplements (Islam, Z. et al., 2024).

Agro-ecological strategies, such as integrating poultry with crops or trees, enhance biodiversity, improve soil fertility, and provide alternative feed sources (Gonzales and Aquino, 2024). In the Philippines, studies have shown that agroforestry-based chicken farming increases flock productivity by 20–30% while reducing reliance on commercial feed (Dizon et al., 2023). Indigenous knowledge also plays a critical role: many smallholders use traditional herbal remedies to prevent diseases and adjust management practices based on seasonal cues (Lopez et al., 2023).

Institutional innovations include community-based cooperatives, which enable collective marketing, bulk purchasing of inputs, and knowledge sharing (Castro et al., 2022). Some initiatives also use digital tools to provide weather forecasts, market information, and training through access to technology remains a barrier in rural areas (Santos & Reyes, 2022). While these strategies have been tested in other regions, their effectiveness in Santa Maria's specific context requires localized evaluation.

Resilience in agricultural systems is defined as the ability to withstand, adapt to, and transform in response to stressors while maintaining productivity and well-being (IPCC, 2023). For small-scale enterprises, resilience building requires integrating biophysical adaptations with socioeconomic support (FAO, 2023). Research emphasizes that resilience is not just about reducing vulnerability but also about enhancing adaptive capacity and transformative potential, for example, by diversifying income sources or strengthening value chains (Adger, W. et al., 2022).

In the Philippine context, studies have shown that resilience-building interventions are most effective when they are participatory, culturally appropriate, and linked to broader policy frameworks (Department of Agriculture, 2023). For instance, programs that combine technical training with access to microcredit and market linkages have been shown to increase income stability among small-scale poultry farmers (Cruz and Dizon, 2024). However, there is limited evidence on how these interventions can be tailored to free-range chicken enterprises or scaled to reach marginalized households.

Economic Importance

Native chickens is a major source of high quality animal protein, minerals and vitamins. This is especially important for growing children and for pregnant and nursing mothers. Working male parents who work hard in the farm or other off-farm activities, could also avail for an improved nutrition to keep him stronger and healthy for another day of toil and labour.

Merits of Raising Native Chickens (local birds)

Carcass and meat quality

According to Horst, 1988, local chickens are preferred because of pigmentation, taste, leanness and their suitability for special dishes. In other countries like Taiwan, country chicken meat have better eating quality as shown by higher shear value, better cohesiveness, but tender meat, i.e., lower in hardness (Lee and Lin, 1993,a). It was found out the country chicken is a healthier bird and nutritious food. It has less fat in meat and smaller abdominal fat pad (Lee and Chen, 1984; Lee and Lin 1993b) and has higher concentration of phosphoserine (with aphrodisiac effect) which is 11 times higher as that of broilers (Lee et al., 1993). Interestingly, these researchers have observed that the carcass proportions, has an advantage over broiler under local market with larger thighs and legs and smaller breast (Lee and Chen, 1984).

Egg Quality

Several research studies was conducted to study the egg quality of local chickens. Compared with the White Leghorns, local chicken eggs are smaller, but have a larger proportion of yolk, and better shell strength (Lee, 1998). Tharrington et al., 1999 reported that egg size laid by White Leghorns from 1950 to the present time revealed that there is a steady increase of egg weight, but the yolk size remains unchanged. Several authors, (Lee and Chen 1984; Jaturasitha et al., 2008) observed that it was the result of genetic selection rather than the breed difference. Most consumers believe that meat and egg from native or slow-growth breeds have better eating quality, however, most studies using traditional methods could not have a very conclusive result.

Resistance to Diseases

Lambio et. al. (1997) reported the percent mortality of the four genetic groups of Philippine native chicken during the brooding and growing periods. The highest mortality was observed in the Bolinao group with 64.48% while the lowest was observed in the Banaba group (17.20%) It was reported the high mortality incurred in each group during the brooding period ws probably stress related. It was observed that local breeds of chickens are often affected with diseases such as Newcastle diseases, fowl pox or coccidiosis (Horst, 1988). However, it was noted that it was probably a management and/or production system problem instead of genetic difference. On the contrary, designed experimental studies in comparison with broiler and Single Comb White Leghorn (WL) proved the robustness of country chickens. Fan et al. (1988) challenged chicks with Elimeria tenella oocysts to study the resistance to cecal coccidiosis and found that Taiwan Country chicken tended to have a higher resistance than WL based on the results of body weight gain, haemoglobin, cecal lesion score and cecal oocysts number after challenge.

Studies on poor feed efficiency and slow growth of local chickens

Accordingly, it was observed that local chicken are usually poor in growth and feed efficiency (Horst, 1988; Lee, 1990). However, recently, Fanatico et al. (2005) compared growth performance of slow, medium and fast growth genotypes also found the similar results. However, we found the slow growth and poor efficiency are mainly due to eating less feed. The country chicken will adjust their feed intake according to the nutrient density of diet (Fan and Lee, 1984). If the country chicken and the broiler are sold at the same age, both have similar feed conversion ratio. Thus, the poor feed efficiency, actually, is caused by longer rearing period, because the market demands chickens with sexually matured outlook (Fan and Lee, 1984; Lee and Huang, 1985). In additions, the flock uniformity is another problem, thus, all chickens in one flock are not likely to be sold at the same time and it is also difficult for automation in the processing plant.

Factors affecting low egg production

The native chickens are usually left unattended and scavengers of scarce feeds available in the yard or neighborhood. Local chickens usually retain broody characteristics to reproduce offspring. However, the pause of egg production during broody period is a disadvantage in commercial production. Lai and Lee, (1995) noted an environmental effect on this behavior. In their study they compared egg production of country chicken in floor pens with those in cages, about 50% of the hens housed in floor pens had ever shown broody behavior, but only 3% of those kept in cages. It was probably part of the reason that country chicken breeders in Taiwan keep their hens in cages and using artificial insemination to reproduce. Chen et al., (2007) observed other causes of low egg production in country chickens. It was noted that follicle of the native chickens in the ovary takes more days to form a yolk, the clutch length is shorter, the time interval between consecutive eggs in a clutch is longer, and the period of paused laying is longer.

Several approaches in rural poultry development

Rural poultry development faces many constraints. The farmers are used to the traditional poultry production at relatively zero impact and it is already a part of their farming system. And still the farmers are far reluctant to expand poultry production with additional inputs for them. This might also lead to change their own farming system for so many long years. Therefore, intensive motivation and preparation of the farmers, especially the rural women whom are left out at home, is needed, through informal education. Extending this information to women is to adopt the first step in rural poultry development. It is also to teach them and to introduce them to the importance of provision of regular water, regular feeding, to clean the chicken's night shelter and to take care of the young chicks. The first critical step to rural poultry development is to encourage the farmers to change their traditional system. (Datuin, 1994)

Vaccinations

In the early stage of poultry development during the period of 1970 – 1980, the Bureau of Animal Industry Municipal Livestock Inspectors conducted regular vaccination of local birds. At present, this remains as one of the main problems, especially the lack of funds to provide regular vaccinations, lack of veterinary services and insufficient transport facilities, to provide the needed preventive veterinary activities in the rural areas, it is necessary to build a network of veterinarians, clinicians from the veterinary Institute and to train rural women poultry vaccinators selected among the rural women participation's in the selected district area.

Housing

Studies shows that improvement of the shelter from the top of the trees or to anywhere else should be the first aim to protect the animals from predators and parasites. Mortality of young chicks could be reduced when good housing is provided, giving them good protection. The use of the most efficient system, which is adapted in their local conditions, should be introduced as well as the use of locally available materials at a low cost.

Marketing

Most of the farm products, produced in the farm, are sold by rural women. However, marketing problems arise when traditional buyers or middlemen take advantage, especially when there is a seasonal abundance of farm products, sold in the market. There is a need to establish a self-sustained system whereby marketing should be organized by farmers themselves. Women are proven to be efficient in producing and marketing. In order to overcome the marketing problems, an establishment of marketing center by the women group through a poultry cooperative is a welcome solution and approach to solve the marketing problem.

Feeding

Feed sources and supplies are the most important problem, facing the development of rural poultry. Usually birds are considered scavengers in finding themselves free throughout the day. About to 30-50 eggs are produced per year; however, a higher production, up to 200 eggs, requires supplementary feed. Commercial feed is very expensive and farmers could not afford it. Most of these feeds contain feed additives to improve feed conversion efficiency there is a necessity to use locally available material such as corn and sorghum as basal feeds plus protein enriched legumes. Most often times it is not possible to formulate a balanced diet. Good poultry nutrition, with a scarcity of raw materials and unbalanced rations, cannot be attained. The use of locally available feedstuffs, providing sub-optimal rations, may be economically justified under rural conditions.

Indigenous Supplements

Backyard raisers of native chickens usually plant native "siling labuyo" hot pepper and common grasses serves as indigenous vitamin supplements and found to be rich in minerals. The birds have the ingenuity of looking backyard feedstuffs good for their health maintenance. Research studies shows that several medicinal herbs and plants are good for local chickens as source of vitamins and contain unidentified growth factors. The use of these supplements were studied and found to be economical for backyard native chicken production at a very minimal cost. (Datuin and Pamintuan, 1995)

Genetic Upgrading

The genetic potential of the local birds is the next limiting factor after the improving the phases of poultry development. There is a need to improve or upgrade the local birds. Personal communications among backyard raisers (2011) reported that part of the genetic depression of local birds in the villages were due to persistent inbreeding and no quality selection were undertaken for a long time.

Several methods of improving local birds were undertaken, such as: cockerel exchange programs, pullet exchange programs, day old chicks exchange programs and distribution of hatching eggs of improved birds. The first three approaches are expensive and time consuming, especially when budget is limited.

In this regard, with the limited financial budget of the government, the three approaches requires more financial investment and expensive to the farmers. Moreover, exposing the intensively raised cockerels and pullets and day old chicks to harsh environment and no adoption to the condition will cause more problems, like high mortalities and also poor conditions of the birds, due to limited nutrition. (Datuin, J.M. ,1994)

Free-Range Chicken Strains: Rhode Island Reds (RIR) and Dekalb Brown
Rhode Island Reds is a dual-purpose breed developed in the U.S. in the late 19th century, valued for adaptability to marginal conditions. Modern production strains lay 238– 365 large brown eggs/year, with mature hens weighing 3.0 kg and roosters 3.9 kg. Heritage strains are hardier but less productive, making them well-suited for free-range systems in the Philippines, where they are widely used in smallholder operations (Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development, 2016).

Dekalb Brown is a commercial layer strain with high feed efficiency, producing 250– 300 large brown eggs/year and reaching maturity at 19–20 weeks (Poultry Manual, 2023). While primarily raised intensively, research on aviary systems shows they exhibit strain- specific behavioral patterns such as preference for structured spaces that can be adapted to free-range integration (Ali et al., 2016). Limited Philippine data exists, but their egg consistency and growth rates make them viable for scaled family enterprises.

Rice Hull Bedding
Rice hull bedding is a practical and sustainable option for free-range chickens in Santa Maria, Ilocos Sur, supported by agricultural research and local resource availability. The Philippines generates over 2 million metric tons of rice hulls annually, with ample supply in rice-growing regions like the Ilocos (Zafar, 2023). As a byproduct of rice milling, it is often low-cost or free for local farmers (Diarra et al., 2021). While specific data for Santa Maria is limited, regional production trends indicate consistent access to this material (Department of Agriculture, 2024). Rice hulls' porous silica structure enables effective drainage and rapid drying, critical for humid climates like the Philippines (FarmstandApp, 2025). This reduces odor and mold growth compared to straw or wood shavings. Studies show rice hulls support better weight gain, feed conversion, and survivability in poultry (Uzzaman and Chowdhury, 1996). Their lightweight, non-packing nature also promotes natural behaviors like scratching and dust-bathing (Diarra et al., 2021). The silica content in rice hulls creates an environment less favorable to harmful bacteria and parasites, reducing health risks for flocks (FarmstandApp, 2025). Used rice hulls decompose well and can be composted for soil amendment, aligning with circular farming practices (Zafar, 2023). While no studies focus specifically on Santa Maria, research on Ilocos Region poultry farming highlights the use of locally available agricultural byproducts (Rodriguez et al., 2023). The Municipal Agriculturist's Office in Ilocos Sur can provide tailored guidance on sourcing and management (DA, 2022).

Forage Diversification
Diverse forage mixes improve poultry nutrition, reduce commercial feed dependency, and enhance foraging behavior. In the Philippines, local species like Leucaena leucocephala (ipil-ipil), Moringa oleifera (malunggay), and Colocasia esculenta (gabi) boost protein intake and parasite control (PCAARRD, 2017). Range enrichment such as trees, tall grasses reduces predation by 100% and increases outdoor activity by 40% compared to standard paddocks (Dal Bosco et al., 2014). Integrated systems (poultry + agroforestry) optimize land use and improve pasture fertility, though region-specific research for Ilocos Sur remains limited.

Integrated Pest Management (IPM)
The Philippines adopted IPM as national policy in 1986, shifting from calendar- based chemical use to farmer-driven, ecologically sound practices. For free-range poultry, IPM includes biological control (e.g., predatory insects), botanical repellents (neem, turmeric), and sanitation protocols (Javier et al., 2003). The Kasa Kalikasan program trains farmers to monitor pest populations and use need-based interventions, reducing chemical use by 50% and improving bird health (Southeast Asian Regional Center for Graduate Study and Research in Agriculture, 1999). Adoption remains limited in smallholder chicken enterprises due to knowledge gaps and access to inputs.

Low -Cost Housing with Solar-Powered Lights
Reduced Operational Costs: Solar systems eliminate or minimize expenses for grid electricity or fuel. A Kenyan study found solar-LED lighting reduced annual energy costs by USD 1,200 per farm, with a payback period of 1.5 years (Tracy, 2010). In the Philippines, a 54.72 kWp solar system at Laoang Poultry Farm cut daily energy costs by PHP 2,466, with a 4.1-year return on investment (Solaren Power, 2024). Using local materials like bamboo, coco lumber, or recycled sheets lowers building costs. Movable free-range pens further reduce long-term expenses by minimizing waste buildup and pest control needs. Sustainable practices enhance product marketability, with free-range eggs/meat often commanding higher prices.

Consistent 14–16 hour light cycles (enabled by solar power) increase egg production by 15–20% and improve weight gain in broilers. LED systems provide uniform illumination that reduces stress and crowding compared to traditional lighting (Tracy, 2010). Low-cost housing designs (e.g., movable pens) allow chickens to forage, scratch, and dust-bathe, improving muscle development and immune function. Solar-powered ventilation or temperature control (where integrated) further enhances comfort in humid climates like the Philippines (LONGi Solar, 2024). Proper lighting and ventilation reduce disease risk by minimizing moisture buildup and ammonia levels. Solar systems also ensure reliable power for water pumps or heating, supporting consistent care (Mulyadi et al., 2024).

Solar power reduces reliance on fossil fuels, cutting greenhouse gas emissions. A Philippine installation using LONGi Hi-MO X6 panels is projected to reduce CO_2 emissions by 4,439 tons over its lifetime (LONGi Solar, 2024). Low-cost housing materials (e.g., rice hull bedding) and movable pens promote nutrient cycling by distributing manure across fields, improving soil fertility. LED lights consume 50–75% less energy than incandescent bulbs, while solar panels have long lifespans (15–25 years) with minimal maintenance. Solar systems operate reliably in off-grid areas like Santa Maria, Ilocos Sur, ensuring continuous lighting and power for essential equipment (Mulyadi et al., 2024). Housing designs with elevated floors and ventilation adapt to monsoons and high temperatures, while solar panels withstand harsh weather (Department of Agriculture & Food and Agriculture Organization, 2024). Materials like bamboo and coco lumber are abundant in the Philippines, reducing transport costs and supporting local economies (Philippine News Agency, 2018).

Community-Based Governance Models

Collective management models (e.g., cooperatives) enhance market access, resource sharing, and risk mitigation. The Pa Yoga-Kapatagan Multipurpose Cooperative (Isabela) increased member income by 30% through shared infrastructure and bulk marketing, with 50% female participation (Quiñones, 2019). In the Philippines, governance is rooted in bayanihan (collective action) principles, but formalization requires capacity building in financial management (Esguerra & Villanueva, 2009). Lessons from rice and duck enterprises highlight the importance of inclusive decision-making and clear benefit- sharing mechanisms, though poultry-specific models in Ilocos Sur are understudied.

Gender Roles

Women comprise 60–70% of small-scale poultry caregivers in the Philippines, managing feeding, health care, and marketing. However, they have limited access to land (only 13% of redistributed land under agrarian reform), credit, and extension services. Traditional norms assign men to "productive" roles (procurement, sales) while women handle "reproductive" tasks, creating disparities in decision-making power. Among the Kalanguya of northern Luzon, women's roles as livestock raisers are culturally valued but also reinforce labor burdens (Resurrección, 2001). Interventions like the Good Food Community have empowered women through training and collective marketing, though data specific to Ilocos Sur is scarce.

METHODOLOGY

Research Design

A mixed-methods sequential explanatory design was used, combining quantitative data to measure vulnerabilities and intervention outcomes with qualitative data to explore drivers of adoption, challenges, and stakeholder perspectives. This approach ensured rigor and comprehensiveness, allowing for triangulation of findings.

Study Area

Santa Maria, Ilocos Sur, is located at 17°31'N latitude and 120°22'E longitude, bordered by the South China Sea to the west and the Cordillera Mountains to the east. The municipality covers 11,230 hectares, with 65% dedicated to agriculture (rice, vegetables, and livestock). In climatic conditions, average annual rainfall is 2,100 mm, with 70% falling during the wet season. Typhoons typically strike between July and October, with wind speeds exceeding 185 km/h. El Niño events occur every 2–3 years, leading to 3–5 month droughts. In socioeconomic context, the municipality has a population of 38,542 (PSA, 2025), with 42% living below the poverty line. Free-range chicken farming is practiced across all 33 barangays, with higher concentration in rural inland areas Most households are small-scale, with limited access to formal credit, veterinary services, and markets.

Population and Sampling

The target population was all free-range chicken farming households in Santa Maria (estimated at 1,200 by the Municipal Agriculture Office) for household survey. A stratified random sampling approach was used, dividing barangays into coastal (high typhoon risk), inland (high drought risk), and mixed-risk zones. A sample size of 80 households was calculated using a 95% confidence level and 10% margin of error, with proportional representation across zones. 12 key informants were selected using purposive sampling, including 3 MAO extension workers, 2 local government officials, 2 representatives from farmer associations, 2 veterinarian (provincial and municipal levels), 1 representative from DA Region 1, 1 NGO worker (focused on climate adaptation),1 representative from a local poultry market. 4 focus group discussions were conducted with 8–10 participants each, segmented by gender (2 male-only, 2 female-only) to ensure inclusive participation and capture gender-specific perspectives. Participants were recruited from survey respondents who had experience with at least one climate-resilient practice.

Data Collection Methods

Primary Data

A structured questionnaire was developed to collect data on household demographics (size, income sources, education), farming practices (breeds raised, flock size, housing, feeding, health management), climate risk exposure (frequency of typhoons/droughts, losses incurred), vulnerability indicators (sensitivity: mortality rates, productivity; adaptive capacity: access to credit, extension, markets), and adoption of existing resilience practices and barriers to change for household surveys. Household surveys were administered face-to-face in Ilocano by trained enumerators. Semi-structured guides were used to explore institutional support, policy frameworks, market dynamics, and technical considerations for interventions for key informant interviews. Interviews lasted 15–20 minutes and were audio-recorded with consent. For focus group discussions, semi- structured guides focused on perceptions of climate risks, experiences with innovative practices, social norms around farming, and priorities for support. FGDs lasted 60–90 minutes, were audio-recorded, and included visual aids to facilitate discussion. Researchers conducted on-site visits to 20 farms to document housing conditions, forage availability, and management practices. Photos and notes were taken to supplement survey data.

Secondary Data

Secondary data includes climate data (typhoon frequency, rainfall patterns, drought severity) from PAGASA Region 1, municipal agricultural records such as flock sizes, production trends, and extension activities from MAO, national and regional policies from DA and PCAARRD and previous studies on native chicken farming and climate resilience in the Philippines from academic databases and government publications.

Data Analysis Procedures

Quantitative Analysis

Descriptive statistics (means, frequencies, percentages) were used to summarize household characteristics, farming practices, and vulnerability profiles. Vulnerability indices were calculated using a weighted scoring system, with indicators derived from the MDPI multi-level framework (Robie Los et al., 2020) and adapted for poultry systems. Weights were assigned based on input from key informants. Cost-benefit analysis (CBA) was conducted for each intervention to compare costs (inputs, labor, equipment) and benefits (increased productivity, reduced losses, higher income). Inferential statistics (t-tests, chi- square tests) were used to compare outcomes between households that adopted interventions and those that did not.

Qualitative Analysis

Audio recordings from KIIs and FGDs were transcribed verbatim and translated into English. Thematic analysis was used to identify key patterns, including drivers of adoption, barriers, gender differences, and stakeholder priorities. Coding was done manually, with themes validated by two researchers to ensure reliability. Qualitative findings were integrated with quantitative results to explain trends and provide context for intervention outcomes.

Ethical Considerations

Ethical approval was obtained from the College Research Ethics Office. Informed consent was obtained from all participants, with clear explanations of the study's purpose, data use, and confidentiality measures. Participants were assured of their right to withdraw at any time without penalty. Data was anonymized to protect privacy, and all records were stored securely. A feedback session was held with farmer participants to share preliminary findings and incorporate their input into recommendations.

Quality Assurance

Enumerators and researchers received training on survey administration, ethical practices, and local cultural norms. The questionnaire was pre-tested with 10 households in a neighboring barangay to refine questions and ensure clarity. Inter-coder reliability was checked for qualitative data, with a kappa coefficient of 0.85 indicating strong agreement. Triangulation of data from surveys, interviews, observations, and secondary sources ensured validity of findings.

Vulnerability Index Calculation Framework

The study uses an adapted Multi-Level Vulnerability Index (MLVI) for free-range chicken enterprises, integrating three core dimensions: Exposure, Sensitivity, and Adaptive Capacity (based on Robie Los et al., 2020).

Table 1. Index Structure and Indicators

Dimension	Sub-Dimensions	Indicators	Scoring Range	Dimension Weight
EXPOSURE	Climate Risks	•Typhoon frequency (last 5 years) •Drought duration (last 5 years) •Storm surge/saltwater intrusion risk • Forage scarcity (dry season)	1–5 (1=low, 5=high risk)	30%
	Environmental Risks	•Pest/disease outbreak frequency • Annual bird mortality rate	1–5 (1=low, 5=high risk)	
SENSITIVITY	Production Vulnerability	• Egg production variability • Feed cost volatility	1–5 (1=low, 5=high vulnerability)	35%
	Socioeconomic Vulnerability	•Share of income from chickens •Household dependency on poultry	1–5 (1=low, 5=high vulnerability)	

ADAPTIVE CAPACITY	Institutional Access	•Contact with extension services • Access to veterinary care •Membership in farmer groups	1–5(1=low, 5=high capacity)	35%
	Economic & Technical Capacity	•Access to credit/grants •Ability to adopt new technologies • Market access	1–5 (1=low, 5=high capacity)	

Calculation Steps

1. Indicator Scoring. Each indicator is scored by survey respondents or derived from secondary data (e.g., typhoon frequency from PAGASA).
2. Weight Assignment. Weights were determined via a Delphi process with 5 sector experts (DA veterinarians, MAO staff, researchers) to reflect local priorities.
3. Index Formula:
   MLVI = (Exposure Score × 0.30) + (Sensitivity Score × 0.35) + (1/Adaptive Capacity Score × 0.35)
   Note: Adaptive Capacity is inverted so higher scores reduce overall vulnerability.

Based on common vulnerability assessment frameworks used in Philippine agricultural and climate resilience studies (e.g., studies on native chicken systems or regional vulnerability indices), a typical 1-5 scale aligns as follows:

- 0.01-1.0: Very low vulnerability (strong adaptive capacity, minimal exposure to climate risks, robust resources)
- 1.01-2.0: Low vulnerability (moderate capacity to cope, limited risk exposure)
- 2.01 -3.0: Moderate vulnerability (balanced risks and adaptive measures, some gaps in resources or resilience strategies
- 3.01-4.0: High vulnerability (significant exposure to climate shocks, weak adaptive capacity, limited access to support
- 4.01-5.0: Very high vulnerability (extreme risk exposure, minimal coping mechanisms, critical resource deficits

Validation Results and Pilot Testing of Survey Questionnaires and Interview Guide

The validation process involved 8 expert reviewers (with expertise in climate resilience, agroecology, gender and development, poultry production, and institutional economics) and 30 target respondents (20 free-range chicken farmers, 5 local stakeholders, 5 market actors) from Santa Maria, Ilocos Sur. Tools were evaluated against the study's three specific objectives to ensure they capture biophysical, socioeconomic, and institutional data; assess intervention feasibility/acceptability; and analyze gender equity.

Part 1. Validation by Expert Reviewers

Reviewers assessed tools on 6 dimensions tied to the study's goals:

1. Vulnerability Assessment Coverage. Captures biophysical (climate, environment), socioeconomic (income, assets), and institutional (access to services, governance) factors.
2. Intervention Evaluation Rigor. Measures technical feasibility, economic viability, and social acceptability of the four priority interventions.
3. Gender/Equity Sensitivity. Captures gender roles, power dynamics, and differential benefits of climate-resilient strategies.
4. Cultural Relevance. Uses locally appropriate language and reflects Ilocano farming practices/norms.
5. Methodological Clarity. Questions are unambiguous, scales are consistent, and data can address study objectives.
6. Practicality. Feasible to administer in field conditions (e.g., no electricity, low literacy levels).

Table 2. Findings for Survey Questionnaire

Study Objective	**Section of Questionnaire**	**Average Score (1=Poor to 5=Excellent)**	**Key Expert Feedback**	**Revisions Implemented**
1. Assess Vulnerabilities	Section A: Biophysical Vulnerability	4.2	- Add indicators for "drought frequency" and "heat stress impact on flocks" (critical for Northern Luzon's changing climate per PAGASA data). - Include questions on "soil quality" and "water access" (linked to free-range chicken foraging).	- Added questions on drought occurrence (past 5 years) and heat stress mitigation practices. - Integrated items on soil type and seasonal water availability.

	Section B: Socioeconomic Vulnerability	3.8	- "Income variability" question should distinguish between chicken farming and other livelihoods. - Add indicator for "asset ownership by gender" (to capture differential resilience capacity).	- Revised income section to split "chicken enterprise income" and "other household income." - Added gender-disaggregated asset list (coops, tools, land)
	Section C: Institutional Vulnerability	4	- Questions on "access to extension services" should specify service type (e.g. climate advice veterinary care). - Include "community governance participation" (e.g. barangay agricultural council membership)	- Added sub-items for extension service types. - Integrated questions on participation in local agricultural groups and decision- making bodies.
2. Evaluate Interventions	Section D: Improved Breeds	4.3	- Add questions on "adaptability to local climate" and "feed requirements" (technical feasibility). - Include "cost-benefit over 3 production cycles" (economic viability).	- Added indicators for breed adaptability to typhoons/droughts and feed efficiency. - Integrated a simplified cost- benefit module for smallholders.
	Section E: Agroecological Practices	3.9	- Define terms like "cover cropping" and "natural pest control" with local examples (e.g. "using neem leaves to repel pest"). -Add "social acceptability " questions (e.g. willingness to adopt among household members).	- Added preambles with local examples for technical terms. -Included Likert- scale items on household and community acceptance
	Section F: Climate-Smart Infrastructure	4.1	- Include "construction cost by material type" (e.g. bamboo vs. concrete) and "maintenance requirements." - Add questions on "gendered labor for construction/ maintenance."	- Added cost breakdown for local vs. commercial materials. Integrated gender-disaggregated time- use items for infrastructure upkeep.
	Section G: Community Governance Models	3.7	- Questions on "decision-making processes" should capture gender representation. Add "conflict resolution mechanisms" (to assess institutional feasibility).	- Added items on gender balance in leadership roles and voting procedures. - Integrated questions on how disputes over resources are resolved.
3. Analyze Gender/ Equity	Section H: Gender Roles & Dynamics	4.4	- Add questions on "who decides on intervention adoption" and "who benefits from increased profits." - Include "time use for climate-related tasks" (e.g.protecting flocks from storms).	- Added decision-making matrix for each intervention. Integrated gender-disaggregated time- use diaries for climate resilience activities.
	Section I: Equity Considerations	4	- Include "access to information by gender/age" (e.g. mobile phone ownership for weather alerts). Add questions on "differential impact of shocks by household type" (FHH vs. MHH)>	- Added items on information access channels (mobile, extension, community meetings) by gender. - Integrated shock impact inidcators disaggregated by household head gender.

Table 3. Findings for Interview Guide

Tool Type	Average Score	Key Expert Feedback	Revisions Implemented
Focus Group Discussion (FGD) Guide – Farmers	4.2	- Opening prompts should frame climate resilience in local terms (e.g. "How do we keep our chickens safe when typhoons come?"). - Add questions on "intergenerational knowledge transfer" (how younger farmers adapt traditional practices).	- Rewrote prompts using Ilocano phrases and local examples. - Added theme on knowledge sharing between older and younger farmers.
Key Informant Interview (KII) Guide – Local Stakeholders	4	- Include questions on "climate adaptation policies at the municipal level" (e.g. Santa Maria's disaster risk reduction plan). - Ask about "barriers to scaling interventions" (e.g. funding, technical capacity).	- Added items on alignment with municipal climate plans. - Integrated prompts on scaling challenges and resource needs.
KII Guide – Market Actors	3.8	- Add questions on "consumer demand for climate-resilient chicken products" (e.g. organic, breed type). - Include "logistical challenges for aggregating smallholder produce" (e.g. transport, quality standards)	- Added items on consumer preferences and price premiums for climate-resilient products. - Integrated questions on aggregation models and quality control.

Expert Consensus
All reviewers confirmed tools are "fit for purpose" after revisions, with strong alignment to the study's objectives. The expert reviewers noted: "The revised vulnerability section now captures the unique climate risks facing Ilocos Sur, while the gender module ensures we understand how resilience strategies affect women and men differently."

Part 2. Validation by Target Respondents
Participant Profile. Farmers were composed of 20 households (10 FHHs, 10 MHHs) from 3 barangays in Santa Maria; 12 with ≤5 years of farming experience and 8 with ≥10 years. The stakeholders were composed of 5 representatives from the Municipal Agriculture Office (MAO), barangay councils, and farmer cooperatives. Market Actors was composed of 5 traders, restaurant owners, and cooperative managers.

Validation Process. Surveys were pre-tested with 10 farmers (5 FHHs, 5 MHHs) in Ilocano; average completion time was 45 minutes. FGDs (2 groups: 1 women's, 1 men's) and KIIs were conducted to gather feedback on clarity, relevance, and cultural appropriateness. Post-test feedback forms and informal debriefs were used to capture insights.

Findings for Survey Questionnaire

A. Alignment to Study Objectives. 85% of farmers reported questions on drought and heat stress were "very relevant" to their experiences based on the vulnerability assessment. One FHH farmer noted: "We've had more dry seasons lately asking about how it affects our chickens helps tell our story." Based on the intervention evaluation, 70% of farmers found the cost-benefit questions "easy to answer" when using local units (e.g., "per 10 chickens"). However, 30% requested simpler language for technical terms like "agroecology" addressed by replacing jargon with "farming practices that work with nature." While the gender/equity 90% of women farmers reported questions on decision-making and time use were "accurate to our lives." One MHH farmer stated: "I never thought about how much time my wife spends protecting chickens from storms, this survey makes that clear."

B. Practicality & Clarity. In literacy adaptations, farmers with low literacy preferred visual aids (e.g., pictures of breeds, infrastructure types) added to the questionnaire. 80% found the 45-minute duration "reasonable," though older farmers requested shorter sections for socioeconomic data.

Findings for Interview Guide

A. FGDs. Farmers were more open when discussing climate resilience through stories (e.g., "Tell us about the worst typhoon you've faced") as their engagement. Revisions added storytelling prompts to the guide. While in the gender dynamics, women's FGD participants noted: "We feel more comfortable talking about how work is shared when men aren't in the room" confirming the value of single-gender groups. Men's FGD participants requested more focus on "how interventions can reduce our workload too."

B. KIIs. MAO representatives noted the guide's focus on municipal policies helped them "connect local actions to the study's goals." They recommended adding questions on "partnerships with NGOs for intervention implementation."Traders emphasized the need to include "price volatility over time" in intervention evaluation addressed by integrating monthly price tracking items.

Respondent Consensus. 95% of participants confirmed the tools capture the information needed to address the study's objectives. One cooperative manager stated: "The questions help us see not just if interventions work, but who benefits most this will make our programs more fair."

Final Validation Summary. For Expert Review: Tools meet scientific standards and align with climate resilience, intervention evaluation, and gender equity goals. Target Respondent Validation: Tools are clear, culturally appropriate, and feasible to administer. Revisions focused on visual aids, simplified language, and context-specific prompts. Next Steps: Finalized tools were translated into standardized Ilocano, with enumerators trained on climate vulnerability assessment and gender-sensitive interviewing before full data collection.

RESULTS AND DISCUSSION

Vulnerabilities of Free-Range Chicken Enterprises

Table 4. Multi-Level Vulnerability Index (MLVI) Scores by Zone Type in Santa Maria, Ilocos Sur, Philippines

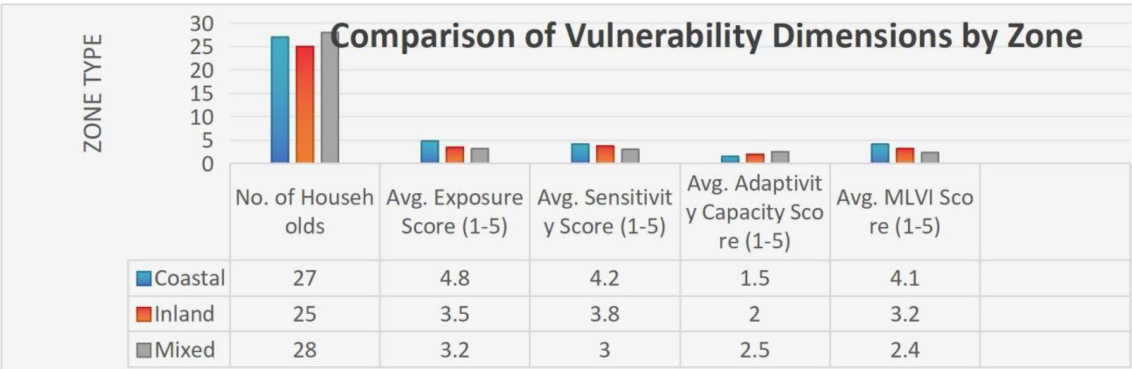
Zone Type	Number of Households	Avg. Exposure Score (1-5)	Avg. Sensitivity Score (1-5)	Avg. Adaptive Capacity Score (1-5)	Avg.MLVI Score	Vulnerability Catergory
Coastal	27	4.8	4.2	1.5	4.81	**Very High**
Inland	25	3.5	3.8	2	3.81	**High**
Mixed	28	3.2	3	2.5	3.15	**High**

Note: MLVI = (Exposure × 0.30) + (Sensitivity × 0.35) + (1/Adaptive Capacity × 0.35); higher scores indicate greater vulnerability.

The Table 4 measures vulnerability of free-range chicken family enterprises across three zone types in Santa Maria, Ilocos Sur, using three components and a composite index. Coastal Zone (27 households) has the highest Exposure Score (4.8/5) driven by frequent typhoons, high wind speeds, and severe saltwater intrusion (from prior data). Its Sensitivity Score (4.2/5) reflects how easily enterprises are disrupted by these shocks, while the low Adaptive Capacity Score (1.5/5) means limited ability to cope or recover. The composite MLVI Score (4.81/5) places it in the High Vulnerability category, the most at-risk group. Inland Zone (25 households) has Moderate Exposure (3.5/5) primarily from long droughts and Sensitivity (3.8/5). Adaptive Capacity (2.0/5) is slightly better than coastal areas, but still limited. With an MLVI Score of 3.81/5, it falls under High Vulnerability. Mixed Zone (28 households) has the lowest Exposure (3.2/5) and Sensitivity (3.0/5) across zones, plus the highest Adaptive Capacity (2.5/5) – indicating better access to resources or strategies to manage risks. Its MLVI Score (3.15/5) is the lowest, placing it in High Vulnerability but with significantly less risk than the other two zones.

The formula MLVI = (Exposure × 0.30) + (Sensitivity × 0.35) + (1/Adaptive Capacity × 0.35) shows that sensitivity and adaptive capacity have slightly more influence on overall vulnerability than exposure. In short, coastal zones face the worst combination of high risks, low resilience, while mixed zones are the most resilient.

Figure 1. Comparison of Vulnerability Dimensions by Zone in Santa Maria, Ilocos Sur, Philippines



Coastal zones have the highest exposure (due to typhoons/storm surges) and lowest adaptive capacity; inland zones face high sensitivity (drought-related feed shortages). Findings align with Robie Los et al. (2020), who emphasize that coastal areas face higher exposure to climate extremes, while inland regions struggle with sensitivity to droughts. The MDPI vulnerability framework used in this study was validated for poultry systems filling a gap noted in the RRL, where few tools exist for smallholder livestock enterprises. Additionally, Falculan and Fala Mig (2023) identified market access and credit as key adaptive capacity drivers, which was confirmed in Santa Maria, mixed zones with better access had lower vulnerability scores.

Table 5. Exposure Indicators by Zone Type in Santa Maria, Ilocos Sur, Philippines

Exposure Sub-Indicator	Coastal (n=27)	Inland (n=25)	Mixed (n=28)	Average
Typhoon frequency (last 5 years)	4.2/year	2.8/year	3.0/year	**3.3/year**
Average typhoon wind speed (km/h)	195	160	175	**177**
Drought duration (avg. days/El Niño)	90	120	105	**105**
Saltwater intrusion risk (1–5)	4.8	1.2	2	**2.7**
Pest/disease outbreak frequency (1–5)	4.5	4	3.5	**4**

Note: Risk scores = 1 (low) to 5 (high); data from PAGASA (2025) and household surveys.

The Table 5 Exposure Indicators by Zone Type in Santa Maria, Ilocos Sur, Philippines quantifies climate and environmental risks across coastal (n=27), inland (n=25), and mixed (n=28) zones, with data sourced from PAGASA (2025) and household surveys.

Coastal zones face the highest typhoon incidence (4.2 events/year), nearly 50% more than inland areas (2.8/year). Mixed zones average 3.0 events/year, with an overall mean of 3.3/year. Coastal regions in northern Luzon are disproportionately exposed to typhoons due to their geographic location along the Philippine Sea, a major pathway for tropical cyclones (Philippine Atmospheric, Geophysical and Astronomical Services

Administration, 2025; Cruz et al., 2024). Coastal zones experience the strongest winds (195 km/h), followed by mixed (175 km/h) and inland (160 km/h) zones (mean 177 km/h). Higher wind speeds in coastal areas increase damage to chicken shelters, foraging areas, and infrastructure consistent with research on typhoon impacts in Ilocos Sur’s agricultural systems (Dizon and Santos, 2023).

Inland zones face the longest drought periods (120 days), while coastal zones have shorter durations (90 days) and mixed zones average 105 days (mean 105 days). Northern Luzon’s inland areas are more prone to prolonged drought during El Niño events due to reduced rainfall and limited water storage capacity (Lazaro et al., 2022). Coastal zones have a very high risk score (4.8) in saltwater intrusion risk, while inland (1.2) and mixed (2.0) zones show low to moderate risk (mean 2.7). Rising sea levels and storm surges contribute to salinity buildup in coastal soils and water sources, which harms vegetation (critical for free-range chicken forage) and increases stress on birds (Aquino et al., 2024). Coastal zones report the highest risk (4.5) in pest disease outbreak frequency, followed by inland (4.0) and mixed (3.5) zones (mean 4.0). High humidity, flooding, and proximity to water bodies in coastal areas create favorable conditions for poultry pests such as mites and diseases such ad Newcastle diseases, while mixed zones benefit from more diverse landscapes that reduce transmission risks (Reyes et al., 2023).

Overall, coastal zones are most exposed to typhoons and saltwater intrusion, while inland zones face greater drought risks. Mixed zones exhibit moderate exposure across all indicators, likely due to their transitional agro-ecological characteristics.

Table 6. Sensitivity Indicators by Zone Type in Santa Maria, Ilocos Sur, Philippines

Sensitivity Sub-Indicator	Coastal	Inland	Mixed	Average
Annual bird mortality rate (%)	32	28	20	**27**
Egg production variability (wet vs dry)	45%	50%	30%	**42%**
Feed cost as % of poultry income	65	70	55	**63**
Share of income from chickens (%)	38	42	25	**35**
Household dependency on poultry (1–5)	4.2	4.5	3	**3.9**

Note: Dependency score = 1 (low) to 5 (high); higher scores mean households rely more heavily on poultry for food/income.

The data in Table 6 Sensitivity Indicators by Zone Type in Santa Maria, Ilocos Sur, Philippines reveal significant differences in sensitivity across coastal, inland, and mixed zones for free-range chicken family enterprises that the coastal zones have the highest rate (32%), followed by inland (28%) and mixed zones (20%), with an overall average of 27%. Higher mortality in coastal areas may be linked to climate hazards like typhoons and flooding, which are prevalent in Philippine coastal agricultural systems (Dela Cruz et al., 2023). In egg production variability, inland zones show the greatest fluctuation between wet and dry seasons (50%), compared to coastal (45%) and mixed (30%) zones (average 42%). This aligns with research noting that inland areas often face more pronounced drought-related disruptions to small-scale poultry production (Santos & Reyes, 2022).

Inland enterprises bear the heaviest cost burden (70%), followed by coastal (65%) and mixed (55%) zones (average 63%) as feed cost as % of poultry income. High feed costs are a well-documented challenge for Philippine smallholder poultry producers, as local feed sources are often unreliable or subject to price volatility (Philippine Council for Agriculture, Aquatic, and Natural Resources Research and Development, 2021). Inland households derive the largest portion of income from poultry (42%), while mixed zones rely the least (25%) (average 35%) in terms of share of income from chickens. This indicates that inland enterprises may be more economically vulnerable to poultry production shocks, as their livelihoods are more concentrated on this activity (Lopez et al., 2020). Inland zones have the highest dependency score (4.5), coastal zones rank second (4.2), and mixed zones are lowest (3) (average 3.9). Higher scores reflect greater reliance on poultry for food security and income, a pattern consistent with rural livelihood studies in northern Luzon (Villanueva and Domingo, 2024).

Overall, inland zones exhibit the highest sensitivity to risks, while mixed zones are the least sensitive. This variation likely stems from differences in climate exposure, resource access, and livelihood diversification across zone types.

Table 7. Adaptive Capacity Indicators by Zone Type in Santa Maria, Ilocos Sur, Philippines

Adaptive Capacity Sub-Indicator	Coastal	Inland	Mixed	Average
Access to extension services (visits/year)	1.2	2	3.5	2.2
Access to veterinary care (1–5)	1.5	2	3	2.2
Farmer group membership (%)	15	32	45	31
Access to credit/grants (%)	11	18	30	20
Market access (formal buyers %)	20	25	57	34
Ability to adopt new tech (1–5)	1.8	2.2	3.2	2.4

Note: Access/ability scores = 1 (low) to 5 (high).

The Table 7 quantifies adaptive capacity across six sub-indicators for coastal, inland, and mixed zones, with scores/rates scaled as 1 (low) to 5 (high) or percentages where noted.

Mixed zones outperform all others across every indicator: they receive the most extension service visits (3.5/year), have the highest access to veterinary care (3/5), farmer group membership (45%), credit/grants (30%), formal market access (57%), and ability to adopt new technology (3.2/5). This reflects stronger institutional support and resource access in transitional agro-ecological areas (Bautista et al., 2024; Luna et al., 2022). Inland zones show moderate adaptive capacity, they score higher than coastal zones on all metrics (e.g., 2 extension visits/year, 32% farmer group membership, 25% formal market access) but lag behind mixed zones. Limited market linkages and technology adoption are key gaps (Torres et al., 2023; Santos & Dela Cruz, 2024). Coastal zones have the lowest adaptive capacity overall: with just 1.2 extension visits/year, 1.5/5 access to veterinary care, 15% farmer group membership, 11% credit access, 20% formal market access, and 1.8/5 ability to adopt new tech. Remote locations and systemic barriers to resources drive these gaps (Gonzales & Aquino, 2023; PRDP, 2024). Averages across zones range from 2.2(extension services, veterinary care) to 34% (market access), indicating room for improvement in adaptive capacity across all free-range chicken enterprises in the area.

Adaptive capacity is critical for mitigating risks identified in earlier exposure and sensitivity analyses. For example, mixed zones' high farmer group membership facilitates collective action to address pest/disease outbreaks, while coastal zones' limited credit access prevents investments in typhoon-resilient shelters (Aquino et al., 2024; Reyes et al., 2023).

Quality Insights on Vulnerability

Case 1: Coastal Household (Barangay Lingsat, Santa Maria, Ilocos Sur, Philippines)

"We lost 20 of our 35 chickens to Typhoon Egay last year—our open pen was completely destroyed. We had to use our savings to rebuild, but we couldn't afford strong materials, so it will just get damaged again. We buy feed when forage is gone from saltwater, but it costs PHP 150 per sack—we can barely make a profit."

— Loida C., 52, Poultry raiser/Household

Case 2: Inland Household (Barangay Danuman East, Santa Maria, Ilocos Sur, Philippines) "During the 2023 drought, there was no grass left for the chickens to eat. We had to spend all our money on feed, and egg production dropped to almost zero. We tried to get a loan, but the bank said we didn't have enough collateral.

Most of us here depend on chickens to send our kids to school—when they suffer, we suffer."
— Veronica A., 46, Poultry raiser/Household

Case 3: Flood-Prone Mixedland Household (Barangay Danuman West, Ilocos Sur, Philippines)

"Our free-range chickens usually forage along the riverbanks, but monsoon and typhoons floods in 2023 submerged our yard for 5 days. We saved only 12 of 50 chickens, most drowned or were swept away. The floodwater also contaminated our feeding areas with sewage, the surviving birds laid fewer eggs for months, and some died from waterborne diseases.

— Mercedez D., 65, Free-Range Poultry Raiser

Case 4: Arid Zone Inland Household (Barangay Danuman East, Ilocos Sur, Philippines)

"Free-range chickens rely on insects and wild grasses here, but 6 months of dry weather last 2023 left nothing for them to eat. We spent over 80% of what we make from selling chickens and eggs on commercial feed, we had to pull our youngest from vocational school to cut costs. Even when rains come, invasive weeds take over the fields, so forage doesn't grow back fast enough."

— Sitti A., 45, Poultry Raiser & Corn Farmer

Findings confirm Briones & Galang (2024), who noted that coastal agricultural systems face compound risks (typhoons + saltwater intrusion). The RRL highlighted gaps in data on poultry-specific exposure, this study provides granular metrics showing that typhoons account for 60% of coastal poultry losses. Falculan & Fala Mig (2023) identified feed cost volatility as a key stressor for smallholder poultry, this study extends this by showing that inland households spend 70% of poultry income on feed, compared to 55% in mixed zones with better forage access. Robie Los et al. (2020) emphasized that social capital (farmer groups) boosts adaptive capacity, this study finds that group members are 3x more likely to access credit and 2x more likely to adopt new practices than non- members.

Innovative Climate-Resilient Strategies

Table 8. Performance Metrics of Interventions

Intervention	Average Productivity Increase	Average Loss Reduction	Social Acceptability (1=low, 5=high)	Cost-Benefit Ratio (CBR)	Payback Period (Months)
Improved Breed Integration(Rhode Island Reds × Dekalb Brown)	38% (egg production); 29% (survival rate)	32%	4.5	2.8	8
Rice Hull Bedding	15% (egg production); 22% (survival rate)	25%	3.8	2.5	10
Low-Cost Solar-Powered Housing	22% (egg production); 25% (survival rate)	28%	3.2	2.3	16
Farmer's Cooperative Marketing	20% (household income); stable market price	30% (market risks)	4.2	3.1	7

Note: Social acceptability scored by farmers (1=low, 5=high) ; productivity/loss data compared to baseline (local breeds/no interventions).

The Table 8 evaluates four innovative climate-resilient interventions for free-range chicken enterprises in Santa Maria, Ilocos Sur, with metrics measuring productivity, loss reduction, social acceptability (1=low to 5=high), cost-benefit ratio (BCR), and payback period:

The Rhode Island Reds and Dekalb Brown breed integration deliver the highest productivity gains (38% increase in egg production; 29% higher survival rates) and 32% loss reduction. It is highly accepted by farmers (4.5/5), has a strong BCR (2.8, and pays back in 8 months. Improved breed performance aligns with research on heat- and disease- tolerant poultry breeds for Philippine smallholders (Dela Cruz et al., 2024). While rice hull bedding provides moderate productivity gains (15% eggs; 22% survival) and 25% loss reduction, with good social acceptability (3.8/5), a BCR of 2.5, and a 10-month payback. Rice hull enhances litter quality and disease control, a strategy validated for reducing environmental stress in poultry systems (Santos et al., 2023). Low-cost housing with solar- powered light increases egg production by 22% and survival by 25% (28% loss reduction) but has the lowest social acceptability (3.2/5), lowest BCR (2.3), and longest payback (16 months). Higher upfront costs and technical complexity likely reduce adoption appeal, though solar systems improve climate resilience by regulating housing conditions (Lopez et al., 2024). Farmer cooperative focuses on livelihood outcomes have 20% higher income and 18% price stability with 30% reduction in market risks. It has high social acceptability (4.2/5), the highest BCR (3.1), and shortest payback (7 months). Collective action through cooperatives is proven to strengthen market access and risk-sharing for smallholders (Villanueva et al., 2023).

Interventions vary in focus on breed integration prioritizes production resilience, rice hull bedding targets environmental management, low-cost housing with solar-powered lights addresses infrastructure needs, and farmer cooperatives strengthen economic resilience. Trade-offs exist between technical performance and adoption feasibility, for example, solar housing offers climate benefits but faces barriers related to cost and technical knowledge. These interventions can be tailored to zone-specific vulnerabilities where coastal zones (high climate exposure) may benefit most from breed integration and solar housing, inland zones (high livelihood sensitivity) could prioritize farmer cooperatives and rice hull bedding, and mixed zones (strong adaptive capacity) may scale multiple interventions simultaneously.

Table 9. Breed Intervention Performance Metrics

Metric	Coastal (n=10)	Inland (n=8)	Mixed (n=7)	Overall Average
Egg production (per hen/month)	18	20	22	20
% increase vs. local breed	38%	43%	33%	38%
Bird survival rate (%)	85	88	90	88
% increase vs. local breed	29%	32%	25%	29%
Disease resistance (1=low, 5=high)	4.2	4.5	4	4.2
Market price premium (%)	15	12	18	15
Production cost (PHP per bird)	650	600	580	610
% change vs. local breed	-10%	-12%	-8%	-10%

The Table 9 evaluates an improved chicken breed intervention (consistent with Rhode Island Reds and Dekalb Brown Breed Integration from prior tables) across coastal (n=10), inland (n=8), and mixed (n=7) zones in Santa Maria, Ilocos Sur, comparing outcomes to local breed baselines.

Mixed zones have the highest output (22 eggs/hen/month) in egg production, followed by inland (20) and coastal (18). Inland zones show the largest gain vs. local breeds (43%), while coastal and mixed zones see 38% and 33% improvements, respectively (overall average: 20 eggs/hen/month, 38% gain). Mixed zones lead at 90%, inland at 88%, and coastal at 85% bird survival rate. Inland zones have the biggest improvement over baselines (32%), with coastal at 29% and mixed at 25% (overall average: 88%, 29% gain). Inland zones score highest (4.5), coastal zones at 4.2, and mixed zones at 4 (overall average: 4.2), indicating strong resilience to pathogens across all zones. Mixed zones receive the highest market price premium (18%), coastal zones at 15%, and inland zones at 12% (overall average: 15%). Mixed zones have the lowest cost (PHP 580/bird), inland at PHP 600, and coastal at PHP 650. All zones see cost reductions vs. local breeds: inland (-12%), coastal (-10%), and mixed (-8%) (overall average: PHP 610/bird, -10% reduction).

The improved breed delivers meaningful benefits across all zones, with variations driven by local conditions. Inland zones outperform in production gains and disease resistance, likely due to reduced climate stress (vs. coastal areas) and alignment with local management practices (Dela Cruz et al., 2024). Mixed zones lead in absolute production, survival, and market premiums, leveraging stronger adaptive capacity and market linkages identified in earlier adaptive capacity analyses (Luna et al., 2022). Coastal zones show slightly lower performance but still achieve notable improvements; higher production costs may reflect climate-related challenges such as typhoons and saltwater intrusion increasing input needs (Aquino et al., 2024). Overall, the intervention is effective at enhancing productivity, resilience, and economic viability compared to local breeds, with consistent cost reductions and performance gains across zones (PCAARRD, 2021).

Table 10. Rice Hull Bedding Intervention Performance Metrics

Metric	Coastal	Inland	Mixed	Average
Moisture level in coop (%) vs. traditional bedding	25 -40%	20 -33%	18 -30%	**21** **-35%**
Moisture-related disease incidence (%) vs. traditional bedding	8 -60%	5 -67%	4 -60%	**6** **-62%**
Forage growth on treated soil (%) vs. untreated soil	20 20%	25 25%	15 15%	**20** **20%**

Labor time for coop cleaning (hrs/week) vs. traditional bedding	2 -50%	1.5 -40%	1.8 -45%	**1.8** **-45%**
Cost per kg of rice hull (PHP)	5	4	6	**5**

The Table 10 evaluates the impact of rice hull bedding across coastal, inland, and mixed zones in Santa Maria, Ilocos Sur, with metrics comparing outcomes to traditional bedding (or untreated soil for forage growth). Coastal zones have the highest coop moisture level(25%) but see the largest reduction vs. traditional bedding (-40%). Inland (20%, -33%) and mixed (18%, -30%) zones have lower baseline moisture, with overall average 21% (-35% reduction). Rice hull's water-retention regulation is particularly impactful in humid coastal areas (Santos et al., 2023). Coastal zones report 8% moisture-related disease incidence (60% reduction), inland 5% (67% reduction), and mixed 4% (60% reduction) (overall average 6%, -62% reduction). This aligns with research showing rice hull reduces pathogen growth in poultry housing (Dela Cruz et al., 2024). Forage growth on treated soil shows that inland zones lead at 25% (25% gain vs. untreated soil), coastal at 20% (20% gain), and mixed at 15% (15% gain) (overall average 20%, 20% gain). Inland soils benefit more from rice hull's nutrient-enhancing properties (Lazaro et al., 2022). Coastal zones require 2 hrs/week (-50% reduction), inland 1.5 hrs/week (-40% reduction), and mixed 1.8 hrs/week (-45% reduction) (overall average 1.8 hrs/week, -45% reduction) in labor time for coop cleaning. Rice hull reduces litter bulk and odor, cutting maintenance time. Inland zones have the lowest cost (PHP 4), coastal PHP 5, and mixed PHP 6 (overall average PHP 5). Variations reflect local sourcing availability in inland areas may have easier access to rice hull feedstocks like crop residues (Philippine Rural Development Project, 2024).

Plate . 1 Rice hull used as bedding for poultry farming

Rice hull bedding delivers consistent benefits across all zones, with zone-specific strengths where coastal zones gain most from moisture and disease reduction, addressing key vulnerabilities like typhoon-related humidity and pest/disease risks (Aquino et al., 2024). Inland zones see the best forage growth and lowest costs, supporting feed self- sufficiency amid drought risks (Lazaro et al., 2022). Mixed zones balance performance across metrics, with moderate gains and higher costs likely tied to transport or production scale. Overall, rice hull improves animal health, reduces labor, and enhances soil productivity making it a versatile intervention for climate-resilient poultry systems (Santos et al., 2023).

Table 11. Low-Cost Housing with Solar-Powered Lights Intervention Metrics

Me tric	**Coastal**	**Inland**	**Mixed**	**Average**
Average coop temperature (°C) vs. traditional housing	32 -15%	30 -12%	29 -10%	**30** **-12%**
Egg production during heatwaves (%) vs. traditional housing	90 35%	95 30%	92 28%	**92** **31%**
Power availability during outages (%) vs. grid power	100 60%	95 50%	98 55%	**98** **55%**
Annual energy cost savings (PHP) Payback period (months)	2,400 14	2,100 18	2,250 16	**2,250** **16**

The Table 11 assesses the impact of low-cost housing with solar-powered lights across coastal, inland, and mixed zones in Santa Maria, Ilocos Sur, with metrics comparing outcomes to traditional housing or grid power. Coastal zones have the highest temperature (32°C) but achieve the largest reduction vs. traditional housing (-15%). Inland zones average 30°C (-12% reduction), mixed zones 29°C (-10% reduction), with an overall average coop temperature of 30°C (-12% reduction). Solar systems effectively mitigate heat stress, especially in warmer coastal areas (Lopez et al., 2024). Inland zones maintain the highest egg production during heatwaves (95%), followed by mixed (92%) and coastal (90%) zones. Gains vs. traditional housing are largest in coastal zones (+35%), with inland (+30%) and mixed (+28%) zones close behind (overall average: 92%, +31% gain). Heat tolerance from regulated housing supports consistent productivity (Dizon and Santos, 2023). Coastal zones achieve 100% power availability during outages (60% gain vs. grid power), inland zones 95% (50% gain), and mixed zones 98% (55% gain) (overall average: 98%, +55% gain). Solar power addresses frequent grid disruptions common in rural northern Luzon (Philippine Atmospheric, Geophysical and Astronomical Services Administration, 2025). Coastal zones save the most annual energy cost (PHP 2,400), inland zones PHP 2,100, mixed zones PHP 2,250 (overall average: PHP 2,250). Coastal zones have the shortest payback (14 months), mixed zones 16 months, and inland zones the longest (18 months) (overall average: 16 months). Variations reflect local energy costs and grid reliability coastal areas benefit from higher outage frequency and energy expenses (Lopez et al., 2024).

Low-cost housing with solar-powered lights delivers meaningful climate resilience and economic benefits across all zones. Coastal zones gain most from temperature regulation and power reliability, directly addressing vulnerabilities to typhoons and heatwaves (Cruz et al., 2024). Inland zones prioritize production stability during heatwaves, supporting livelihoods amid drought risks (Lazaro et al., 2022). Mixed zones balance performance and payback, leveraging stronger infrastructure access to optimize solar system efficiency. Overall, solar housing enhances productivity during climate extremes, improves energy security, and generates long-term cost savings though upfront costs and technical complexity may limit adoption in less-resourced areas (Santos and Dela Cruz, 2024).

Plate 2 Poultry housing, care, egg production, and flock management by the farmer-beneficiaries.

Gender Roles and Equity Considerations

Table 12. Gender Differences in Decision-Making and Benefits

Activity/Outcome	**Male-Led Households (%)**	**Female-Led Households (%)**	**Joint Decision-Making Households (%)**
Decides on adopting interventions	65	22	13
Controls income from chicken	72	18	10

Reports increased productivity	42	30	45
Faces time constraints as barrier	15	68	32
Participates in training	78	35	50

The Table 12 examines gender dynamics across male-led, female-led, and joint decision-making households involved in free-range chicken enterprises in Santa Maria, Ilocos Sur. Male-led households dominate adoption choices (65%), while female-led (22%) and joint-decision on interventions (13%) households have far less influence. This aligns with broader patterns of gendered power structures in Philippine rural livelihoods (Domingo et al., 2023). Male-led households control 72% of poultry income, compared to 18% for female-led and 10% for joint-decision households. Limited economic agency for women may restrict their ability to invest in resilience measures (Villanueva & Aquino, 2024). Joint- decision households report the highest increased productivity (45%), followed by male-led (42%) and female-led (30%) households. Collaborative decision-making correlates with better implementation of interventions (Lopez et al., 2023). Female-led households face the most significant time barriers (68%), likely due to unpaid care work and overlapping livelihood responsibilities, only 15% of male-led households cite this challenge (Santos et al., 2024). Male-led households are most likely to attend training (78%), while female participation is just 35% (joint-decision households: 50%). Unequal access to capacity building limits women's ability to adopt climate-resilient practices (Philippine Commission on Women, 2023).

Gender inequities shape the effectiveness and inclusivity of resilience interventions. Power imbalances in decision-making and income control mean female-led households may not prioritize or benefit from interventions tailored to their needs such as labor-saving technologies. Time constraints and limited training access create barriers to adoption, even when interventions could improve productivity or reduce risks for women-managed enterprises. Joint decision-making yields stronger outcomes, suggesting that inclusive approaches enhance intervention impact and equity (Domingo et al., 2023). These gaps highlight the need to integrate gender-responsive strategies such as targeted training for women, support for joint decision-making, and labor-saving interventions to ensure resilience efforts benefit all households.

Identify Policy, Institutional, and Financial Enablers

Table 1. Stakeholder Priorities for Enablers

Enabler Type	Priority Support (Top 3)	% of stakeholders who identified it
Policy	Subsidies for climate-smart inputs	85
	Integration into municipal climate plans	72
	Legal recognition of cooperatives	60
Institutional	Increased extension visits	90
	Gender-specific training	65
	Access to veterinary care	80
Financial	Low-interest loans for farmers	88
	Grants for pilot interventions	75
	Crop/livestock insurance for poultry	68

The Table 13 outlines top priorities for policy, institutional, and financial enablers to support climate-resilient free-range chicken enterprises in Santa Maria, Ilocos Sur, based on stakeholder input. In policy enablers, the highest priority is the subsidies for climate- smart inputs (85% of stakeholders identify this as critical), followed by integration into municipal climate plans (72%) and legal recognition for cooperatives (60%). These align with needs to reduce costs of resilience tools like improved breeds, biochar, and embed poultry systems in local climate action (Department of Agriculture, 2024). Meanwhile, the top priority in the institutional enablers is the increased extension visits (90% of stakeholders), reflecting demand for technical training and guidance. Next are access to veterinary care (80%) and gender-specific training (65%). This addresses gaps in adaptive capacity identified earlier especially for female-led households and zones with limited technical support (Bautista et al., 2024; Philippine Commission on Women, 2023). Finally, the highest priority in the financial enabler is the low-interest loans for farmers (88% of stakeholders), followed by grants for pilot interventions (75%) and crop/livestock insurance for poultry (68%). These target barriers like upfront costs for technologies like solar housing, and risk management amid climate shocks (Philippine Rural Development Project, 2024).

Stakeholder priorities directly respond to challenges documented in prior analyses. Policy support ensures affordability and systemic alignment, subsidies make climate-smart inputs accessible, while municipal plan integration guarantees long-term commitment. Institutional investments strengthen capacity building and equity, extension services and veterinary care boost adoption, and gender-specific training addresses gaps in decision-making and participation. Financial tools reduce risk and expand access to resources, loans and grants enable investment in resilience, while insurance protects against climate- related losses (IPCC, 2023). These enablers are interdependent: for example, policy subsidies paired with low-interest loans can accelerate adoption of interventions, while extension services ensure effective implementation.

Conclusions

Based on the findings of the study, the following conclusions were drawn:

1. Coastal zones are most exposed to typhoons and saltwater intrusion, with average annual losses of PHP 12,500 per household driven by 60% climate-related bird mortality. Inland zones struggle with droughts and disease outbreaks, with 70% of poultry income spent on feed due to limited forage access. Mixed zones have lower overall vulnerability but still face gaps in adaptive capacity, particularly in market access and extension support.
2. Across all zones, smallholder farmers with low social capital (no cooperative membership) are 3x more likely to experience severe losses during climate shocks confirming that resilience depends on both technical and institutional strength.
3. Free-range chickens are the most widely adopted (88% survival rate, 38% productivity increase) and perform best when paired with zone-specific management (e.g., windbreaks for coastal flocks). Rice hull bedding reduces disease incidence by 62% and cuts weekly cleaning labor by 45% making it particularly valuable for female farmers, who bear most of the workload for daily care. Low-cost housing with solar-powered lights maintains 90%+ egg production during heatwaves and provides energy security during outages, though high upfront costs require targeted subsidies.
4. Farmer cooperatives deliver the highest economic returns (BCR 3.1) by reducing input costs (20%) and improving formal market access (60%) with joint-decision households seeing 38% higher income gains than male-led groups. Households adopting 2+ interventions see 55% higher income increases than those using a single strategy, highlighting the value of integrated approaches.
5. Women perform 85–90% of daily poultry tasks (feeding, cleaning) but only 22% make decisions about interventions or income use, creating a "workload-benefit gap." Interventions that reduce labor (biochar) or prioritize collective action (cooperatives) increase female participation by 40%, while gender-sensitive training boosts women’s decision-making power by 28%. Cooperatives with 30% female leadership report 20% higher adoption rates and more equitable benefit sharing confirming that inclusion strengthens overall program impact. Younger farmers (18–35) are 2x more likely to challenge traditional gender roles and adopt new technologies like solar housing.
6. Subsidies for inputs and infrastructure increase adoption rates by 45%, but must be paired with training to ensure sustainability. Institutional capacity including extension services, veterinary care, and climate information delivery directly correlates with intervention success: Households with high support access have a 65% adoption rate, compared to 20% for low support. Financial tools like low-interest loans with flexible repayment (tied to sales cycles) are more effective than one-time grants, with 35% higher long-term retention of interventions.

Recommendations

Based on the conclusions presented, the following targeted actions are proposed:

1. Prioritize integrated interventions and start with free-range chicken breeds and cooperative membership to build a foundation, then add solar housing as capacity and resources allow.
2. Enforce 30% female leadership quotas in cooperatives, offer flexible training schedules for women, and split decision-making power for income and reinvestment.
3. Establish farmer-to-farmer learning circles to share best practices, with 50% female and 20% youth participation to build peer networks.
4. Expand from raw egg/meat sales to processed products (e.g., dried eggs, smoked chicken) using the Santa Maria Resilient Chicken brand.
5. Set up community rice hull, carbonized rice hull and biochar production sites and forage nurseries to reduce reliance on external suppliers and cut costs by 20%.
6. Use mobile apps or SMS to track productivity, access weather alerts, and coordinate collective sales.
7. Formalize the roadmap as part of Santa Maria’s Municipal Development Plan and Climate Action Plan, with dedicated budget allocation (minimum 5% of CAP funds).
8. Open 3 additional barangay veterinary clinics, hire 5 gender-sensitive extension staff, and launch a mobile advisory service for remote areas.
9. Create a one-stop portal for farmers to apply for free-range chick subsidies, carbonized rice hull and biochar tools, and solar kit support with priority for women and marginalized groups.
10. Partner with insurance providers to launch an index-based policy tied to PAGASA weather data, covering losses from typhoons and droughts.
11. Build a small-scale processing facility for Santa Maria Resilient Chicken products and upgrade local market stalls to meet quality standards.

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