NAVIGATING UNCERTAINTIES TOWARDS SUSTAINABLE FEED PRODUCTION FOR INDIAN POULTRY AND CATTLE FARMERS

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Dedication

This research work thesis is devoted to the memory of my late father, Sri Binod Bihari Nath, and my late mother, Smt. Rebati Nath, who dreamed of seeing me become a doctor. This work is also dedicated to my wonderful wife, Janapriya, and my daughters, Amrita and Adrita, whose love and incitement always have been a continuous pillar of support. Though I was unable to fulfill my parents' dream, their legacy lives on through the support and aspirations of my family.

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ABSTRACT

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Introduction: India's poultry and dairy farmers often operate under uncertain and challenging conditions. Unpredictable rainfall, limited irrigation facilities, and poor infrastructure make it difficult for farmers to manage livestock effectively. These challenges reduce productivity and income, especially for those who were in rural and semi-urban areas who heavily agricultural dependent and livestock for their livelihoods.

Background: Over the years, various government initiatives have aimed to improve livestock productivity. However, farmers still face major obstacles, such as soil degradation, inadequate veterinary services, and poor access to affordable, sustainable feed. Moreover, market linkages remain weak, further limiting farmers' ability to scale up operations or ensure consistent income.

Aim: This study aims to assess the impact of government interventions in addressing key challenges in poultry and dairy farming, with a focus on sustainable feed production and livestock services.

Research Gap: While previous studies highlight productivity and technological advancements, they often overlook how government policies influence the overall livestock ecosystem. There is a lack of integrated analysis that connects policy impacts to feed availability, breeding programs, and veterinary services in rural India. This research work study seeks to bridge that gap by providing a comprehensive policy-oriented perspective.

Research Methodology: Using a simple random sampling method, various data were collected from 400 farmers across rural and semi-urban regions between 2022 and 2023. A structured questionnaire covering six thematic areas was used. Data analysis included regression and Chi-Square tests.

Results: Findings indicate that technology adoption, improved feed supply, and supportive policies significantly boost productivity and income ($R^2 = 0.297–0.552$, $p < 0.001$; $\chi^2 = 174.987–783.669$, $p < 0.001$). However, inconsistencies in policy implementation persist.

Originality: This study uniquely integrates policy analysis with technological and economic dimensions of livestock farming.

Implications: The findings provides actionable insights for policymakers and stakeholders for improved infrastructure, training, and resource distribution to enhance sustainability in India’s livestock sector.

Keywords: Sustainable livestock farming, Poultry and dairy feed production, Government policies, Veterinary services, Technology adoption, Farmer challenges, Rural agricultural development

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CHAPTER I

INTRODUCTION

1.1 Statement of Problem

Indian farmers deal with various uncertainties in their agricultural practices and associated farming systems such as over-dependence on unreliable rain, lack of irrigation facilities, poverty and illiteracy of the farmers, small land holdings, Erosion of soil by heavy rain, floods and insufficient vegetation cover can lead to a degradation in agricultural output. Poultry farming deals with challenges such as a lack of warehouses, adequate cold storage and increased antibiotic levels that can cause harmful effects such as drug resistance. Major constraints faced by the livestock sector include poor access to organized markets, water sources depletion, inadequate availability of credit, lack of vaccines and vaccination set-up, limited availability of quality breeding bulls, and diversion of fodder and feed ingredients for commercial use.

1.1.1 Overview of the Research Problem

The agricultural sector is witnessing rapid expansion in the livestock industry. Anticipated increment in demand for essential livestock items is projected until 2050. Although livestock farming is essential for feeding the global population and supporting economic growth, it also exerts pressure on natural resources and impacts the environment. A key concern is the substantial emission of greenhouse gases (GHGs) throughout the livestock production process, which adds notably to human-induced GHG emissions (MacLeod et al., 2018).

Considering the aggregate of the agricultural and forestry sectors, livestock singularly constitutes more than 50% of its composition. These attempts are shaped by diverse factors entwined with feed creation, spanning deforestation, the utilization of nitrogen fertilizers, processing, and the movement of goods. Nevertheless, within the domain of livestock, poultry emerges as the category with relatively diminished effects on land occupancy, water usage, environmental stress, and overall footprints. The concept is relevant for both poultry eggs and meat, as highlighted by (De Vries, De Boer in 2010). It's important to recognize that despite its current affordability, the transportation of these products has significant environmental consequences. Poultry meat is extensively traded on a global scale, especially between key regions like Asia, South America, and the EU-28, as indicated by (Vaarst et al. in 2015).

In 2013, Gerbens-Leenes and colleagues conducted a comprehensive exploration of the water footprint associated with domesticated chicken and other meat related production across several nations, including China, Brazil, the United States and the Netherlands. Their investigation illuminated that this water footprint is fundamentally shaped by variables such as the Feed Conversion Ratio (FCR), feed composition, and the provenance of its constituents. It's worth noting that while concentrated feed boasts a higher FCR, it notably amplifies the water footprint in contrast to roughage. This distinction is particularly evident in industrial systems, which distinctly exhibit a diminished water footprint in comparison to alternative systems. This divergence predominantly emanates from the selective breeding of animals in industrial setups, geared toward accelerated growth, restricted mobility, and enhanced FCR. The study also made a discernment between distinct freshwater sources, classifying rainwater as yielding a lesser environmental impact when compared to ground or surface water. Furthermore, the authors accentuated the imperative of contextualizing the influence of poultry production within the framework of local water scarcity, among other pertinent considerations. Clearly, production techniques that demand substantial water utilization are conspicuously unsustainable in regions grappling with water scarcity.

In the realm of feed and food management, a significant concern arises regarding the potential competition between poultry and human populations for protein resources. This issue becomes particularly salient when a substantial portion of protein-rich feed is allocated to animals. The feeding strategies employed in organic poultry farming present a compelling case for analysis, as scrutinized by (Blair 2018) and (Nørgaaard et al. 2021). Within this context, multiple facets of "environmental sustainability" warrant examination, notably in relation to the European Union's directive mandating a transition to 100% organic feed within a stipulated time frame. While the EU has extended the final deadline for this transition to January 2018, permitting up to 5% inclusion of non-organic constituents until then (EU, 2012; 2014), this extension underscores apprehensions regarding the availability of ample high-quality protein sources.

The concept of achieving 100% organic feeding can be realized through an augmented reliance on locally sourced feed materials that neither compete with human nourishment nor necessitate extensive transportation. This methodology is consequently perceived as more sustainable. However, this shift potentially gives rise to a challenge in fulfilling the methionine requirements of poultry. This challenge could potentially lead to inadvertent overfeeding of protein, heightened nitrogen release, potential disease vulnerabilities, and compromised production. This scenario underscores the necessity for a holistic and comprehensive understanding of "adequate feeding" within a systemic framework. This viewpoint entails nurturing animal resilience and accentuating robustness in the domains of feeding practices and poultry management. This notion was initially explored by Horsted and Hermansen in 2007 and subsequently elaborated upon by (Steenfeldt et al. 2013).

In a well-integrated agricultural system, animals assume a pivotal role in a dynamic nutrient cycle. The ideal scenario involves these animals subsisting on resources sourced from the farm itself, a practice that not only optimizes resource utilization but also curtails labour and resource consumption, particularly in terms of non-renewable resources. A crucial benefit lies in the contribution of animal manure to enhancing soil fertility. This intricate ecological cycle is noticeably absent in industrialized animal production systems, which heavily hinge on the transport of resources. In such industrial setups, the byproduct of animal manure metamorphoses into a 'waste' stream, necessitating management akin to handling pharmaceutical remnants, secondary products, controlling odours, or dealing with deceased animals. A substantial dimension of environmental pollution related to the food industry and trade hinges on the extensive use of fossil fuels. These fuels are indispensable for activities like cultivating and conveying feed, transporting live animals and poultry products, and providing controlled temperatures within poultry facilities. Given the adaptable nature of poultry farming to a wide array of local circumstances, the disproportionate reliance on resource transportation might be seen as dispensable in meeting the crucial requirement for supplying human protein (Vaarst et al., 2015).

In 1999, the use of two particular types of growth enhancers in poultry feed was officially banned (Alagawan & Abd El-Hack, 2020). Despite this measure, the widespread application of antibiotics in livestock farming remains a pressing issue across 25 European Union nations. According to the Third ESVAC report, around 8,420 tonnes of antibiotics—excluding coccidiostats—were distributed for animal farming in 2011. Within the EU, poultry is responsible for nearly 13% of the total antibiotic use, with the majority being delivered through premixed feed or oral liquid forms, accounting for roughly 84% of usage. These are largely used for group treatments in pig and poultry production systems. It's evident that any production system reliant on medication and posing a risk for the development of antibiotic-resistant bacteria or environmental pollution from medication residuals cannot be rightfully labelled as 'sustainable'. This is especially significant if these medications are administered for preventive measures and/or in the form of mass medication.

Humanity has accomplished the domestication of approximately 30 distinct animal species, yielding an impressive compilation of around 8,000 documented breeds. Among these, poultry alone boasts a multitude of breeds. This diverse array of breeds is primarily nurtured by small-scale farmers globally. These farmers play a crucial dual role—not only do they boost worldwide poultry meat and egg production, but they also help preserve the rich diversity of livestock breeds. Many of these breeds showcase attributes like regional adaptation, versatility, indigenous heritage, and suitability for various farming contexts. In contrast, contemporary industrial systems predominantly lean on specialized single-purpose breeds, often earmarked for either broiler or layer production.

The primary attributes of broilers demonstrate a moderate to high level of heritability, contrasting with lower heritability observed in traits associated with poultry egg production. Concerns regarding selection plateaus in layer strains were articulated six decades ago. Controlled comparison trials began in the 1950s, 1960s, and 1980s, with modern genetic lines introduced starting in 1989. These studies revealed a consistent yearly improvement of approximately 0.7% in feed efficiency, calculated as the weight of eggs produced per unit of feed consumed. Similar improvement rates were indicated in industry comparisons extending until 2009 (Hill et al., 2016b). Despite modern birds rarely exceeding one egg daily, they demonstrate early maturation, lower weight, extended production periods, and the laying of relatively larger eggs, contributing to heightened efficiency in feed utilization (Hill et al., 2016a). The potential consequences of breed elimination are profound. Such actions not only result in the forfeiture of natural genetic diversity, colloquially referred to as "genetic wealth," but also extinguish the prospects for acquiring to diverse environments and circumstances, including unpredictable scenarios such as climate variations (FAO, 2015). Moreover, the ethical dilemma of culling millions of male chicks immediately following hatching engenders valid concerns, thus prompting reflections on the sustainability of these practices.

Numerous inquiries have been undertaken regarding the labour conditions of individuals working within industrial farms, particularly with a dedicated focus on poultry farms. These investigations encapsulate two distinct dimensions of social considerations related to human welfare: 1) the physical and overall health of individuals concerning their working conditions (encompassing both farm proprietors and labourers), and 2) the fairness of employment arrangements, encompassing elements such as access to health insurance, just remuneration, and the entitlement to engage in collective bargaining. Notably, poultry farmers and their families are exposed to an escalated susceptibility of contracting antibiotic-resistant bacteria and developing sensitivities to antibiotics. The gravity of these risks has resulted in the classification of poultry farmers in The Netherlands, starting from 2012, as individuals necessitating quarantine and specialized medical attention in the event of hospitalization due to these concerns. Furthermore, exposure to airborne particles stemming from litter and feathers presents supplementary health hazards to poultry farmers, potentially triggering respiratory complications (Le Bouquin, 2014).

(Quandt et al. 2013) organized qualitative interviews with Latino chicken catchers in the United States, focusing on their working conditions. Their findings succinctly revealed that "Chicken catching is characterized by a working environment and organization of work that promotes illness and injuries." Research of this kind highlights the complex connection between occupational health hazards, human rights issues, and workplace environments. In the food production sector, many employees face unfair treatment and endure poor working conditions, largely driven by efforts to reduce the immediate costs of production. Furthermore, a significant portion of contemporary poultry farmers function as contract farmers. This designation denotes their role as "out-growers," supplying their products to larger producers or processors. The specific arrangements and conditions governing these relationships exhibit considerable variation and, in certain instances, significant inequity (FAO, 2011).

Viewed from an ethical standpoint, the consensus is that animal husbandry systems inflicting suffering upon animals are fundamentally unacceptable. Janker and Mann (2020) observed a significant rise in the number of tools developed to assess sustainability in agriculture.

Despite this growth, there remains no unified agreement on what constitutes 'sustainability' or a 'sustainable agricultural system,' particularly from a social perspective. To examine how various tools perceive and incorporate the social dimensions of sustainability, the researchers conducted a qualitative analysis of the content from 87 agricultural sustainability assessment frameworks. Their findings reveal a noticeable divergence in the definition and implementation of the social dimension among these tools. This diversity is influenced by disparities in their backgrounds, objectives, and geographical scopes. The various perspectives have resulted in discrepancies in the integration of contents into the social dimension and the operationalization of its topics. The lack of a standardized understanding of 'social sustainability' in farming is evident, reflecting significant global diversity in production systems. It is evident that the objectives of the developers of the study play a crucial role, often taking precedence over the establishment of a scientific consensus on the meaning of 'socially sustainable.' As a result, numerous assessment tools lack well-defined concepts and strong practical frameworks for measuring social sustainability. Some tools rely on principles from human and labor rights outlined by the United Nations and the International Labour Organization, while others emphasize farmers' views on their overall quality of life. Although common topics like labor standards, community well-being, and social impact appear frequently, there remains a pressing need to revisit and clearly define what social sustainability means within the agricultural sector. This approach would enable the comprehensive integration of all social aspects of sustainability for farms, addressing variations both in geographical and content-related contexts.

Many modern systems frequently fall short in providing animals with ample opportunities to satisfy essential criteria, resulting in situations where specific poultry-rearing practices inflict suffering. For instance, conditions like foot pad dermatitis, which might be linked to rapid growth, can significantly compromise animal welfare, giving rise to atypical behaviours. In certain instances, faster-growing genotypes display imbalanced behavioural patterns, such as an elevated inclination towards rest compared to their slower-growing counterparts (Stadig et al., 2017). Several investigations delve into alternative approaches to the conventional method of feed restriction. One notable strategy involves the implementation of low-density diets for growing female broiler breeders (van der Eijk et al., 2022). These studies have indicated that this tactic leads to diminished hunger and frustration, resulting in reduced stereotypical behaviours and tail pecking. In contrast, activities like dust bathing and other comfort behaviors are observed to increase compared to birds fed standard restricted diets (Nielsen et al., 2011). Nonetheless, further research is necessary to ascertain whether high-fibre diets could amplify the sensation of satiety in birds. Irrespective of the specific animal welfare framework employed, the undeniable truth persists that farm animals, including poultry, possess sentience and merit protection, alongside opportunities to live lives imbued with genuine well-being.

The institutional dimension of sustainability encompass the supervision and management of global systems, with a focus on ensuring institutions' accountability, transparency, and inclusiveness towards their members and representatives, as emphasized in the 'The Rio Declaration' established by the UN in 1992. Nonetheless, the current state of our food regime presents its own set of challenges. A small group of breeding companies exercises substantial control over a significant portion of the market, thereby obstructing the emergence of smaller enterprises. Moreover, achieving a harmonious balance among the diverse interests intrinsic to the sustainability concept necessitates a meticulous approach to governing these systems. The (European Commission 2001) highlighted, in an introspective analysis of the 'Cardiff Integration Process' initiated in 1998, that there was an inadequacy of coordination in the formulation of policies that address the various environmental, economic, and social facets of sustainability. This observation stands despite the European Union's array of policies dedicated to these dimensions.

Often, endeavours directed towards achieving goals within a particular policy domain unintentionally hinder progress in other spheres..., and it is not uncommon for solutions to problems to require the involvement of policymakers operating in different sectors or governmental tiers. This dynamic significantly contributes to the persistence of unsustainable trends over time. In essence, policies crafted to stimulate economic growth, for instance, might inadvertently impede initiatives aimed at advancing social development. This mode of governance extends to responsibilities such as ensuring environmental preservation in distant regions like South America or promoting sustainable local production and markets in regions like Africa or Asia. Furthermore, these initiatives might encompass fostering production approaches that contribute to attaining gender balance.

Throughout the annals of history, poultry has been domesticated, nurtured, and savoured across the world for centuries. Nevertheless, its role as a dietary staple has undergone substantial transformations over the last century. In the 1920s, poultry meat enjoyed the status of a luxury commodity in the United States. The progression of the US broiler groups into a pioneering "agribusiness" during the 1960s ushered in a paradigm shift in the perception of chicken meat. As the ensuing decades unfolded, chicken meat gradually transitioned into an increasingly accessible "staple food," eventually earning the moniker of being the "cheapest source of protein" (Jackson et al., 2017).

A comparable evolution manifested in the United Kingdom. During the 1940s, the chickens consumed were largely by-products, originating as male chicks from the burgeoning egg industry. Escalating demand and higher pricing for chicken served as potent drivers for the widespread adoption of mass production methodologies. This transformation, in turn, prompted the specialization of production practices and the emergence of an exceptionally efficient industry (Jackson et al., 2017). In Africa, a contemporary trend entails the burgeoning of intensive poultry production in proximity to urban centres (FAO, 2011). Concurrently, considerable volumes of frozen poultry are being exported from subsidized industrial farms within the European Union to nations in Africa and Asia. Notably, in 2012, the Netherlands supplies approximately 119,000 tonnes of poultry meat to various African countries.

Titze et al. (2007) explored how certain trade activities undermine the sustainability of local poultry farming, which otherwise holds promise for improving the livelihoods of rural farmers. The concept of “livelihood” gained widespread attention after the release of the WCED report *Our Common Future* in 1987. At its core, the term refers to the process of making a living and involves the skills, resources, and efforts people use to support themselves (Chambers & Conway, 1991). In this light, backyard or village poultry farming plays a crucial role in reducing poverty and improving food security for households in many low- and middle-income countries (Alders & Pym, 2009).

Today’s agricultural practices often emphasize specialization and streamlining, relying heavily on external inputs to maintain stable and productive conditions. While this method enhances output and efficiency, it also introduces several environmental challenges, such as degradation of natural ecosystems, nutrient loss from soils, disruption of beneficial soil organisms, and rising operational costs (Behera & France, 2016). Large-scale livestock systems—including dairy, poultry, pig farming, and feed manufacturing—also depend substantially on outside resources like commercial feed. This dependence contributes to pollution during both the input production phase and at the local level, due to poor waste management and disposal practices (Paramesh et al., 2021). Furthermore, these highly focused and intensive farming models reduce plant and animal biodiversity and increase the susceptibility of small-scale farmers to climate change effects and market uncertainties (Paramesh et al., 2018).

In India, farming practices that rely heavily on intensive agriculture frequently struggle to ensure consistent income, stable employment, food security, and long-term environmental and energy sustainability. Farmers relying solely on a single type of agricultural activity, like conventional monocropping, often encounter difficulties in maintaining a secure and sustainable livelihood. To address the limitations of specialized, input-driven agriculture, it becomes imperative to adopt an integrated approach which combines crops, livestock, and fishery components. This integration helps ensure nutritional and food security while providing periodic and regular income for farmers (Gill et al., 2009).

Integrated farming systems (IFS), which combine both crop production and livestock activities, are gaining popularity once again, particularly among small to medium-scale farmers working with less than one hectare of land (Behera and France, 2016). This method supports ecological intensification by reducing dependence on external inputs and improving natural processes like nutrient recycling, soil enrichment, environmental sustainability, and overall soil health. Well-managed IFSs are perceived as more secure due to the advantages of operational crop diversification, synergy, and ecological stability (Behera and France, 2014).

In comparison to the conventional rice–wheat system (with net returns of $1258), integrated farming systems (IFSs) that incorporate diverse land-based enterprises demonstrated significantly higher net returns at $5050 (Bhargavi and Behera, 2020). In a study by (Jayanthi et al. 2003), the integration of crops with fish and poultry led to a 25% growth in economic returns in lowland Tamil Nadu. (Das et al. 2013) found that systems combining crops with fish and pig components (pig-based IFSs) or crops with fish and ducks generated substantially greater employment, income, and livelihood opportunities for farmers compared to sole crop cultivation. Another study by (Surve et al. 2014) showcased the adoption of IFSs as a promising and profitable alternative to an existing soybean–wheat cropping system. This transition led to improved returns, job creation, water productivity, and energy output.

Integrated Farming Systems (IFS) are an especially effective strategy for minimizing dependence on external resources and enhancing soil health (Hu et al., 2016). The integration of livestock, fisheries, and other components with crop cultivation has demonstrated improved efficiency in nutrient utilization, nutrient recycling, and soil microbial activity, as evidenced by (Shekinah et al. 2007) and (Sujatha and Bhat 2015). Kerala, India provides a noteworthy example where homestead farming, integrated with livestock, sustains a family of four throughout the year on a modest 0.2-hectare plot, supplying milk, vegetables, and eggs (John, 2014). Resource-constrained small and marginal farmers find IFS particularly significant for meeting protein needs through products like eggs, milk, and meat, a point underscored by (Devendra and Thomas 2002). By optimizing available resources and incorporating elements like legumes, oilseed crops, vegetables, or agroforestry systems, IFS holds the promise of enhancing both food security and nutritional well-being (Wezel et al., 2014).

Determining factors that influence the integration of innovative technology into Integrated Farming Systems (IFS) include education, cropping area, family size, farming experience, and access to weather forecasts (Elahi et al., 2021). Moreover, (Elahi et al. 2018) proposed that productive application of agricultural loans and agro-advisory services significantly aids the acquiring of IFS practices among marginal and small farmers. Given the intricate dynamics of future food and nutritional needs, the establishment of regional IFS in India assumes pivotal importance in meeting these demands. However, the challenge remains to implement production strategies that address food requirements in the face of weather change and its unpredictability.

1.2 Significance of the Study

A deep understanding of the problems faced by livestock farmers in India can help in knowledge advancement through the availability of different government schemes and policies that simultaneously support the farmers in preserving the resources and involve them in different scientific pieces of training. It can also help policymakers implement tools, techniques and policies for farmers, which plays a notable role in supporting farmers in maintaining their resources and increasing their crop yield.

1.3 Research Questions

This research study addresses the following questions:

● What challenges and risks do poultry and livestock farmers encounter in relation to animal nutrition, breeding practices, health management, and access to veterinary care?

● Which existing government policies support poultry and cattle farmers, and what additional measures should be introduced to further benefit them?

● What methods are being used to raise awareness and introduce modern technologies in poultry and livestock farming?

1.4 Research Objectives

This research study intends to explore the uncertainties and obstructions in sustainable feed production in Indian poultry and dairy farmers. Also, the study focuses on understanding the situation of Indian poultry and dairy farmers, especially with regard to government policies on feed production. The purpose of the research includes:

- To identify and analyze the key challenges and risks faced by poultry and livestock farmers in areas such as animal nutrition, breeding practices, health management, and veterinary services.
- To evaluate the effectiveness of current government policies and schemes supporting poultry and cattle farmers and recommend additional policy measures that could enhance their welfare and productivity.
- To examine the strategies and approaches used to raise awareness and promote the adoption of modern technologies in poultry and livestock farming among rural and small-scale farmers.

1.4.1 Hypothesis

The following **null hypotheses (H_0)** have been formulated to judge the impact of government policies, technological adoption, and feed-related interventions on the sustainability and productivity of Indian poultry and dairy farming. **Hypothesis testing** will primarily involve **regression analysis** to determine predictive relationships, and **Chi-Square tests** to assess associations between categorical variables.

- Null Hypothesis 1: The adoption of advanced feed production technologies has no statistically remarkable impact on the sustainability of feed utilization or the economic performance of poultry and dairy farms in India.
- Null Hypothesis 2: Government schemes focused on feed production and distribution do not significantly reduce economic strain or improve the productivity and profitability of Indian poultry and dairy farmers.
- Null Hypothesis 3: Improved access to high-quality feed and veterinary services does not significantly affect livestock health or operational efficiency, and thus has no effect on income levels of farmers.
- Null Hypothesis 4: Participation in training programs and educational interventions on sustainable feed production does not significantly influence the adoption of improved practices among poultry and dairy farmers in India.
- Null Hypothesis 5: Integrating traditional and modern feed production methods does not significantly enhance the resilience of poultry and dairy farms to environmental and economic uncertainties.

Hypothesis Testing Approach

- **Chi-Square Test**: To evaluate associations between unconditional variables (e.g., training participation and adoption rate).
- **Multiple Regression Analysis**: To evaluate the influence of independent variables (e.g., policy support, technology adoption) on dependent variables such as productivity, income, and sustainability metrics.
- **Significance Level**: A p-value < 0.05 will be considered statistically notable for rejecting the null hypotheses.

1.5. Limitations, delimitations, and assumptions

This study is limited by its dependency on self-reported data from 400 farmers, which may introduce response bias or inaccuracies. The sample is confined to rural and semi-urban regions in India, potentially restricting the universality of findings to other geographic or economic contexts. Delimitations include the study's specific focus on poultry and dairy farmers, excluding other livestock sectors. Furthermore, the research timeframe (2022–2023) may not capture long-term policy impacts. It is assumed that respondents provided accurate and honest information and that external variables such as market dynamics or climate factors remained relatively constant during the data collection period.

1.6. Definition of terms

Sustainable Feed Production: The process of generating livestock feed in a way that meets current needs without compromising environmental, social, or economic resources for future generations.

Veterinary Services: Medical services provided to diagnose, treat, and prevent diseases in farm animals.

Policy Effectiveness: The degree to which government policies achieve intended outcomes in improving livestock farming practices and productivity.

Technology Adoption: The uptake and application of modern tools, techniques, or innovations by farmers to enhance livestock health, breeding, and feeding.

Simple Random Sampling: A statistical method where every individual in the population has an equal chance of being selected for participation.

Likert Scale: A psychometric scale used in questionnaires to calculate attitudes or opinions across a continuum of agreement or disagreement.

1.7 Background

Sustainable production is a significant and growing concern in production economics (Li et al., 2014), especially essential for the food and fodder industry, which is the biggest sector for manufacturing in many developing as well as developed countries. The food industry consumes huge amounts of natural resources and deals with demands that are increasing rapidly. However, food production has become more efficient in many key aspects. The food industry deals with the global challenge of sustainable supply. As per an estimate, 175 million people in India are being fed with grain by overpumping of water and 24% of families in India are dealing with foodless days (Brown, 2012). Another significant challenge to the sustainable supply of food is food wastage, with an estimated almost one-third of global food production being wasted or lost on an annual basis (Gustavsson et al., 2011). New challenges have emerged in the food industry such as climate change, localism and fair trade, however, there still exist battles from the past such as public health, farming, waste and food security (Li et al., 2014). There is a rapidly growing issue about the environmental and social sustainability of the food industry. Basic questions associated with everyday life are becoming more necessary and debatable such as the supply, distribution and consumption of food in a sustainable way to avoid compromises, standards and technologies that should be combined to improvise sustainable development, methods to reduce food wastage and operating costs and the impacts of standards on which food supply chains are running and working. Policymakers and stakeholders in the food industry must focus and look beyond their boundaries to develop strategies to make sustainable development in the food industry involving several factors such as social-economic, regulatory, technology, market, environmental and scientific (Li et al., 2014).

The world today is home to over 7 billion people, and to adequately nourish this population, about 2,800 million tonnes of cereals are needed annually. However, global cereal production currently stands at only around 2,100 million tonnes. This shortfall results in widespread undernourishment, especially among those living in developing nations (Rupasi et al., 2014). As urban areas expand, rising incomes and shifting eating habits are driving up demand for protein-rich, animal-based foods. Projections indicate that the global population may reach nearly 9 billion by 2050 (Kharas, 2010), with demand for animal products expected to double by then due to increasing urbanization, economic growth, and population rise. Given the challenges posed by climate change, meeting these future food needs will require a focus on sustainably intensifying livestock production systems.

Food security refers to a condition where every individual in a country has reliable economic, physical, and social access to adequate, nutritious food that aligns with their dietary preferences and fulfills their nutritional needs for leading a healthy and active life (Hoque et al., 2022). Encouraging and expanding livestock farming can play a key role in ensuring food availability for a large segment of the population and supporting long-term food sustainability. Livestock production systems differ in terms of sustainability, which depends on factors such as resource availability, environmental conditions, and the prevailing social and economic settings (Hoque et al., 2022). These livestock systems can include extensive grasslands, and landless and inter cropping systems, which make a notable contribution to human livelihoods and nutrition as well as provide necessary assistance to the ecosystem (Varijakshapanicker et al., 2019). Apart from this, these systems can also cause environmental and nutrient pollution, and if not managed properly can also lead to land degradation. Animal husbandry significantly impacts the environment by contributing to water, soil, and air pollution, alongside the heavy consumption of natural resources like freshwater, fossil fuels, and land. Globally, the livestock sector is responsible for around 18% of greenhouse gas emissions (Steinfeld et al., 2006). To ensure sustainable livestock farming, it is essential that food safety measures are integrated with policy decisions related to infrastructure, public health, nutrition, environmental protection, and poverty reduction. In the absence of such coordination, expanding animal farming operations can lead to harmful outcomes, including the spread of zoonotic diseases. Neglecting public and environmental health policies further exacerbates these risks (Banhazi et al., 2012). However, certain animals like poultry, pigs, and goats can be raised with minimal resources and still provide safe food products (Ahmad et al., 2018).

Dairy farming serves as a vital means of income for numerous landless and small-scale farmers who often raise cattle and buffalo that produce relatively low quantities of milk. By adopting improved animal husbandry practices and investing in high-yield dairy breeds, these farmers can significantly enhance milk production, which not only supports their livelihoods but also provides a nutritious food source for others (Ahmad et al., 2018). Techniques like artificial insemination can aid in developing superior breeds, contributing to higher efficiency. Additionally, educated unemployed youth can consider dairy farming as a viable career path, supplying fresh and affordable milk to consumers. On the other hand, poultry farming requires fewer resources and can also be pursued with minimal investment. Poultry just need care during their early days and are built to survive in harsh weather.

In India, nearly 60% of the population depends on agriculture, making it the country's primary livelihood. The nation's total net sown area is around 142 million hectares, with livestock farming forming a vital part of the agricultural system. As of recent data, the livestock population includes approximately 304.7 million cattle and buffaloes and 215.7 million goats and sheep (Suresh et al., 2012). Crop residues from arable farming serve as a significant feed source for animals. Only about 4.75% of the total cultivated land is devoted to fodder crops, while permanent pastures and grasslands occupy around 12.8 million hectares. Additionally, about 15.6 million hectares of land categorized as wasteland are also used for grazing. Forest-linked grasslands and fodder trees provide supplementary forage resources (Singh et al., 2004). The livestock raised includes commonly domesticated animals such as cattle, buffaloes, goats, sheep, poultry, pigs, and horses, as well as lesser-known species like camels, yaks, and Mithun.

A key characteristic of India's livestock industry is its reliance on non-conventional feed sources such as crop residues, agricultural byproducts, foliage from trees, natural grasses, weeds, and grazing on both harvested fields and communal grazing lands (Dikshit & Birthal, 2010). However, not much optimum output is produced when more resilience for feed is towards crop residues as they lack nutrients. Accordingly, more livestock is kept for meat and milk production as well as work purposes of their owners. India can get more output from limited livestock if healthy animals are utilized with improved and updated equipment and processes, this will eventually reduce the burden on land (Misra et al., 2007). A major challenge in improving livestock productivity is the shortage of adequate feed. To address this, it is essential to evaluate and manage available feed resources effectively, which in turn can boost animal output and contribute to the nation's economic growth. Moreover, timely and informed decisions by stakeholders and policymakers depend on such effective resource management.

Feed resources are the key components of the production systems, whose efficiency determines the economic production. It is very essential to determine the efficiency of the use of feed resources as it primarily determines animal yield and performance (Devendra and Leng, 2011). The efficiency and utilization of available feed resources are justified by two critical factors:

i) The current output of animal-based foods, particularly from ruminant animals, falls short of meeting the anticipated nutritional demands of the population. To bridge this gap, most regions—without exception—will need to double or even triple their production levels by the year 2050,

ii) nutrition and feeding have been observed as the major limitation to ruminant production (Devendra, 1997). Focused attention to this key factor alone can lead to a significant growth in the contribution of animals. Therefore, it is crucial to initiate timely conversations around the availability of animal feeds and overall feed security, especially in the face of fast-depleting resources like fossil fuels, freshwater, cultivable land, and fertilizers—including nitrogen-based ones derived from fossil fuels, along with phosphate and other mineral-based fertilizers (Devendra & Leng, 2011).

The crisis of feed resources is further made up by threatening climate change, increasing food costs and economic crisis, each among these being more crucial than the other (Nellemann, 2009). For instance, the reduction in cultivable land has been limited due to increasing pressure because of human population and urbanization, which the reduction in crop yields has further heightened. At the beginning of 2008 (IMF, 2008), food prices were 150% higher than they had been in 2000 and even though there has been a reduction in food prices, they are still higher the levels from previous years and pose a constant threat. In the past, the affordability of grains, proteins, and energy-rich feeds played a key role in driving the growth of intensive milk and meat production systems, including grain-fed dairy and beef farming (Devendra and Leng, 2011). This also led to the emergence of highly capital-intensive industrial farming, particularly in poultry and pig production near urban centers. However, with rising cereal prices and increasing resource constraints, it is becoming less feasible to maintain the previous growth rates in non-ruminant livestock sectors. Although grain prices might eventually stabilize or drop after surpassing a certain threshold, the costs involved in production may outweigh profits, making such systems economically unsustainable. Moreover, the situation is further complicated by growing competition for food, biofuels, animal feed, and cultivable land. Given these challenges, there is a strong case for shifting focus toward the development of ruminants—such as cattle, sheep, goats, and buffaloes—especially within agro-ecological zones (AEZs). This shift should emphasize the efficient use of agricultural residues, biomass by-products, and alternative feed resources (Devendra and Leng, 2011). This strategy is well-founded due to the diverse benefits these animals offer, particularly their potential for contributing to milk and meat production.

Particularly small farmers are more prone to sight the re-emergence of animal draught power due to the rising fuel costs. In many countries, the underdeveloped ruminant livestock sector—particularly cattle, sheep, and goats—holds significant potential for growth, especially in neglected rainfed regions such as non-irrigated, marginal or less-favoured areas, semi-arid and arid zones, forests, and woodlands (Devendra & Leng, 2011). These regions are typically home to some of the poorest populations. Notably, rainfed regions in Asia make up around 66% of all cultivable land, encompass 85% of arid/semi-arid, sub-humid, and humid priority zones, and support about 63% of the rural population (TAC, 1992). As a result, enhancing ruminant livestock productivity has been identified as a strategic starting point for improving these rainfed areas—contributing to increased animal protein production and greater food security (Devendra et al., 2000). To increase animal productivity and performance on an annual basis, it is necessary to match the primary objectives by ensuring the efficient supply of sufficient dietary nutrients. The approach for the efficient use of feed resources and choice of production systems are together involved as both these components will determine the enhanced performance per animal. The poor immune response is generally associated with low productivity, causing poor health and conditions among animals, so the productivity gains can be influenced by improved protein nutrition alone (Leng, 2005). Currently, the extent to which feed resources are used varies significantly between countries. This variation includes underuse, overuse, partial, full, or even improper use of available feed, all of which have a direct impact on the nation's livestock productivity. These differences are mainly influenced by three key factors: methodological issues, institutional frameworks, and biological constraints.

Farming and livestock rearing are closely connected to the economic, cultural, and spiritual fabric of society, forming the backbone of integrated agricultural practices and contributing significantly to the sustenance of rural communities (Dagar et al., 2017). Livestock contributes significantly by providing essentials such as manure, fuel, draught power, transportation, milk, and meat—often serving as the main income source for small-scale farmers and acting as a buffer against crop failure. It directly supports the livelihood and food needs of nearly one billion people, while also affecting the dietary health and well-being of countless others (Rojas-Downing et al., 2017). Historically, livestock has symbolized wealth and social status across various cultures, and India is recognized as having the world's largest and most diverse livestock population (Singh et al., 2022). As reported in the 20th Livestock Census conducted in 2019, the total livestock population in India reached 535.82 million, showing an increase of 4.6% compared to the figures recorded in 2012. India has a 302.82 million bovine population including yak, buffalo, mithun and cattle and is also home to 57.3% of buffaloes present all over the world and 14.7 % of the cattle population of the world. Despite leading the world in milk production, India continues to face low animal productivity, largely attributed to a significant deficit in livestock feed, which also contributes to widespread malnutrition (Statistics, 2019). No methods can be helpful in sustaining cattle husbandry without noticing the challenges associated with sustainable feed production in the country. Fodder supplies were estimated to be more than 60% in the 1990s but the statistics have minimized to around 50% of the total requirement. Expanding the area used for growing fodder crops is becoming increasingly difficult due to rising competition for agricultural land among various uses (Kumar et al., 2012). Therefore, it is essential to enhance the productivity of fodder crops on the existing farmland to fulfill the growing requirements of the livestock population. In addition to improving output from current arable lands, utilizing non-arable or marginal lands can also help bridge the gap between supply and demand (Vijay et al., 2018).

1.7.1 Agriculture, Dairy and Poultry Farming in India

Agriculture continues to be a foundational pillar of rural India, significantly supporting the country's socio-economic growth and progress toward sustainable development goals. Despite its importance, the sector accounted for just 18.8% of India's Gross Value Added (GVA) during the 2020–2021 financial year (Economic Survey, 2021)., it continues to be the primary source of employment, engaging around 45.6% of the workforce in 2019–2020, including nearly 59.9% of all female workers (Chand & Singh, 2022). Recent research highlights how urbanization has brought noticeable changes in food consumption patterns, as consumers increasingly shift from staple grains to more diverse diets that include fruits, vegetables, meat, and eggs (Pandey et al., 2020). Simultaneously, India remains committed to inclusive and sustainable development. Since gaining independence, national policies have largely focused on boosting economic growth to reduce poverty (Harris & Orr, 2014), while also aiming to ensure household food and nutritional security. The Government of India has consistently pursued development strategies aligned with sustainable development goals, evolving from industrialization efforts in the early post-independence period to broader national development planning frameworks (Adhia, 2013).

India's strategy for national progress has consistently focused on eradicating poverty and hunger as key steps toward building a sustainable society (Chhibber, 2022). To turn this vision into actionable development efforts backed by solid policy frameworks, the Government of India rolls out various agricultural development initiatives. These efforts include: (i) integrated programs aimed at advancing agricultural technologies, (ii) schemes carried out by different state and central development bodies to implement targeted approaches, and (iii) extension activities led by Agricultural Universities that involve refining, evaluating, and promoting agricultural technologies directly to farmers. Since independence, the ICAR has been able to implement six frontline extension programs that are as follows; i) Institution Village Linkage Programme (IVLP) (1995), ii) National Demonstration Project (1964–1965), iii) Lab-to-Land Project (1979), and iv) the Operational Research Project (1972) (Kokate and Singh, 2003). Established in 1974, Krishi Vigyan Kendras (KVKs) were created as district-level institutions to implement frontline agricultural programs. Over time, however, several pressing challenges emerged—such as the widening gap between available technologies and actual crop yields, limited accessibility of advanced farming practices, mismatch between farmer needs and existing technologies, underrecognition of farmers' indigenous knowledge and grassroots innovations, and the growing impact of climate change on agriculture and nutrition in both rural and urban settings. In response to these issues, a novel frontline extension initiative called Farmer FIRST (Farm, Innovation, Resources, Science, and Technology) was introduced to promote more inclusive, farmer-centered development (Venkatesan et al., 2023).

Introduced in 2016, the Farmer FIRST Programme (FFP) focuses on identifying and implementing agricultural technologies that are best suited to the distinct agro-climatic and socioeconomic conditions faced by farmers. Its goal is to support food and nutritional security, especially in the context of a changing climate (Venkatesan et al., 2023). This initiative has consistently relied on stakeholder engagement as a key approach to uncover region-specific challenges, evaluate technological requirements, and design suitable solutions tailored to the farmers' socio-economic, environmental, and agricultural conditions. The approach operates through a hands-on platform that unites diverse stakeholders, encouraging active collaboration to steer the transformation process during the intervention. It also supports institutions in maintaining the benefits gained over time. A key aspect of the Farmer FIRST Approach involves aligning with Sustainable Development Goals (SDGs), encouraging active participation from stakeholders, and adopting a combined approach to technology use (Kokate and Singh, 2003).

SDG-focused interventions include any change in technology inclined towards addressing the major goals of sustainable development that goes beyond technology transfer and is in need of a thorough approach to address the upcoming and rising challenges (Imaz and Sheinbaum, 2017.). Such technology interventions should focus on increasing the yield along with guaranteeing nutritional and food security under the changing climate, especially for the small and marginal farmers in transpire economies such as India (Rao et al., 2016). The Farmer FIRST Program (FFP) interventions are developed to address multiple Sustainable Development Goals (SDGs) through a comprehensive program such as climate action, gender equality, better health and well-being, and zero hunger. From a different viewpoint, the technology assemblage method focuses on selecting and combining technological solutions that align with both social norms and economic feasibility, tailored to meet the needs of varying agro-ecological regions. This approach brings together proven practices from horticulture, crop cultivation, livestock management, natural resource conservation, and integrated farming systems to create holistic models suited to local conditions (Gill et al., 2009).

Dynamic stakeholder engagement includes incorporating the stakeholders such as farmers in the planning, implementation and assessment of the effects of various technology-focused solutions in order to address nutritional and food security issues and institutionalise them to sustain their benefits. To attain this approach, India has developed various pathways since 2015 such as climate-smart agriculture, and sustainable entrepreneurship for the development of grassroots and nutrition-sensitive agriculture (Venkatesan et al., 2023). At present, there is significant potential for expanding Farmer FIRST Programs (FFP). To secure long-term support from stakeholders, it is essential to conduct thorough assessments that highlight the importance of sustained resource commitment.

Dairy farming holds both economic and social significance in India, particularly for smallholder farmers and rural women. As the leading global producer and consumer of milk, India contributes around 17% of the world’s total milk output. The country also possesses the largest population of bovines globally (Khadse and Asia, 2016). With domestic demand steadily increasing, most milk produced is consumed locally or nationally. Approximately 30% of India's dairy production is managed by the formal sector, which includes private enterprises, while the remaining 70% is handled informally (Singh, 2012). Among the organized players, Amul—a prominent dairy cooperative—accounts for about a third of operations (Ramdas, 2015). Despite this, a large number of dairy farmers remain outside formal supply chains, choosing instead to sell their milk directly to end consumers or small businesses like tea stalls and local eateries. Various factors such as privatization and liberalization have led to growth in competition in the milk market, also called as dairy boom in India and the market share of the cooperatives has been overtaken by the private players. Various sources claim that the private division was able to surpass the market share in 20 years attained by the dairy cooperative sector for over a half-century (Sood, 2014).

Considering markets of industrialized countries, with virtual saturations by dairy products, their cooperations are focusing on acquiring Asian Markets especially India which has the highest dairy consumption. This environment full of competition has led to a condition where major dairy cooperatives are under pressure and are rapidly trying to overlap another in order to capture the growing market with the help of practices which are causing harm to the small farmers and their survival (Ramdas, 2015). One of the major key concerns arising in this scenario is the effect of the dairy boom on the small producers under the free market model in India. In India, the dairy sector is predominantly run by smallholders, including landless and marginal farmers, who generally rear fewer than five cows or buffaloes (Khadse & Asia, 2016). The prevailing system is characterized by low investment and correspondingly modest returns, with both production volumes and associated costs kept minimal (Emmanuel & Intodia, 2015). However, there is a slow emergence of large-scale dairy farms, particularly in peri-urban regions, supported by private capital. Among dairy animals, buffaloes are especially favored, contributing over half of the nation's milk output (Islam et al., 2016), primarily due to the richness of their milk in fat content and their resale value for meat.

India has witnessed a notable rise in poultry production and its consumption, growing steadily at a rate of 8–10% annually (APEDA, 2016). Between 2004 and 2012, chicken consumption rose sharply—by 181% in cities and an even higher 256% in rural areas (Mallapur, 2015). The country currently ranks third globally in egg production and sixth in chicken meat output (USDA, 2013). Among all meat varieties, chicken remains the most commonly consumed in India, largely due to religious sensitivities that restrict the consumption of beef (Hellin et al., 2015). Per capita, consumption of poultry in India is 2.5 kg per person, which has increased steadily over the last 10 years. In India, household backyard poultry production is very ubiquitous and is mostly preferred by women for additional income and self-consumption (Khadse and Asia, 2016.). It has great potential of providing sufficient nutrients and additional income and is also crucial for providing livelihood support for rural families, especially women. The traditional structure that characterized India's poultry sector up to the 1960s has now been entirely overtaken by a vertically integrated industrial system. This modern approach relies heavily on contract farming, where large agribusiness companies engage farmers through formal agreements to manage poultry production on their behalf (Mehta & Nambiar, 2007).

In India, nearly 80% of poultry production is dominated by large-scale private commercial enterprises, primarily located in southern regions like Andhra Pradesh, Tamil Nadu, and Karnataka (Hellin et al., 2015), followed by northern states such as Punjab and Haryana. Poultry meat has emerged as the most preferred option, surpassing other protein sources like buffalo, veal, and beef (Ali, 2015). The expansion of this sector is largely driven by the growing middle class and the rise of vertically integrated poultry companies that have brought down retail prices through large-scale production (APEDA, 2016). The increase in poultry farming has also coincided with a surge in domestic maize cultivation. Currently, around half of India's maize yield is allocated to the poultry industry (Kaur et al., 2022). However, during periods of low supply, India has incurred significant costs on maize imports. Although the country insists on importing only non-GMO maize, experts have raised concerns over the potential presence of genetically modified organisms and their unintended impact on native maize varieties (Reuters, 2016).

1.7.2 Indian Farmers and Livestock

In India, the majority of livestock keepers come from small-scale farming families and follow age-old animal husbandry practices. The growth of dairying in the country presents a fascinating journey. Around five decades ago, the onset of the White Revolution marked a turning point, aiming to position India as the global leader in milk production (Gamit et al., 2021). Before this movement, particularly until 1955, milk production was minimal, and the availability of milk per person was notably low. The introduction of the First Five-Year Plan in 1951 brought renewed focus to the country's cattle breeding strategies. It was only by the late 1960s and 1970s that significant initiatives like the Intensive Cattle Development Project (ICDP) and the Key Village Scheme (KVS) were launched, leading to broader adoption of cross-breeding practices among cattle farmers. In India, a significant share of milk comes from smallholder farmers based in rural regions. While milk production is scattered across numerous rural households, the primary demand and market for milk are concentrated in urban centers (Sirohi et al., 2009).

To ensure a stable income for rural dairy farmers and to satisfy the growing demand in urban markets, it is essential to establish a strong connection between these two sectors. One of the key obstacles in this linkage is the perishable nature of milk, which emphasizes the importance of processing within the dairy supply chain to effectively connect producers with consumers (Gamit et al., 2021). Despite the development of substantial dairy processing infrastructure under India's Operation Flood initiative in the cooperative sector, a large portion of milk is still sold in its raw, unprocessed form.

In the year 1970, the beginning and launch of Operation Flood-I revolutionised the dairy sector through the establishment of farmers' co-operatives in various rural areas and connecting those farmers with customers present in urban areas with the help of an enormous system of milk including its fetching, processing and delivering to numerous villages in rural India. The most interesting component of the program was the completion of small dairy milk producers with the help of cooperative societies in India's dairy business. Operation Flood I lasted from 1970 to 1981 with over 15,000 farmers covered by 13,000 village dairy cooperatives. It was further followed by Operation Flood II, which lasted from 1981 to 1985, including 36 lakh farmers as a part of 34,500 village dairy cooperatives, and Operation Flood III, extending from 1985 to 1995, with 9.4 million farmers covered under 73,300 village dairy cooperatives. Numerous bull mother farms were also started to increase the production of crossbred and exotic bulls (National Dairy Development Board, Operation Flood).

Livestock plays an essential role in shaping both the social and economic fabric of rural India. Among the various animal-based ventures, dairy farming stands out as the most widespread and profitable activity. In recent years, there has been a noticeable transition in the makeup of milch animals, with a gradual rise in the number of indigenous cows, replacing the earlier dominance of buffaloes and crossbred cattle (Dhindsa et al., 2014). For millions of farming families, dairy farming offers a dependable and significant source of income (Nalwaya et al., 2018). As a key component of agriculture, animal husbandry significantly contributes to the nation's economy. India boasts the largest livestock population globally, and over 70% of its population remains engaged in agriculture and livestock-related occupations. India ranks on top in milk production with over 187.7 million tonnes of milk produced in 2018-19, out of which 11.3 % and 9.5 % are contributed by indigenous cattle and nondescriptive cattle respectively (Savalia et al., 2019).

In order to receive maximum return from livestock farming, it is necessary to look at the optimum fertility of the animals due to the indirect relation of production with reproductive traits (Verma et al., 2018). Different management practices determine the production potential of livestock, which can vary across agro-climatic areas because of several reasons and factors. Understanding how farmers manage their livestock in a particular region is essential for identifying both the strengths and shortcomings of existing rearing practices. This insight is key to shaping effective policy decisions and targeted interventions (Gamit et al., 2021). Farmers generally avoid confining their animals to one location for extended periods, often not even for a full day or night. Good housing facilities provided to the animals reduce energy wastage and maintain the thermo-neutral zone, as well as provide clean living conditions and reduce the risks of incidences of diseases, protecting them from predators and also providing healthy and better working conditions to the farmers. Various other practices also promote their productivity such as healthcare management practices including deworming and vaccination, ensuring better health of animals. Another significant economic component is the management of reproduction which plays a crucial role in the success of a dairy enterprise. Inadequate detection of estrus has long been recognized as a significant barrier to successful reproductive performance in herds (Gamit et al., 2015).

In India, animal husbandry serves as a primary source of livelihood for over 20.5 million people. While livestock contributes around 16% to the income of small-scale farmers, its average contribution to overall rural household earnings is about 14%. More than 70 million rural households rely on livestock as a secondary or additional source of income (Patel et al., 2017). Approximately two-thirds of the rural population is engaged in livestock-related activities, supporting employment for nearly 8.8% of the country's total workforce. India possesses a rich diversity of livestock, which plays a significant role in the economy by contributing 4.11% to the national GDP and accounting for 25.6% of the gross value of agricultural output (Vikaspedia, 2020).

As per the data from the 20th Livestock Census, India’s total livestock population reached 535.78 million, reflecting a 4.6% growth compared to the previous census. In the same year, the bovine count stood at 302.79 million, marking a 1% rise from earlier figures. There are almost 192.49 million cattle present in the country, out of which 50.42 million and 142.11 million are constituted by exotic/crossbred and indigenous/non-descript cattle populations respectively. As of 2019, India’s buffalo population reached approximately 109.85 million, reflecting a modest growth of just over 1% compared to the last livestock census. The nation’s total milk output stood at 187.75 million tonnes, marking a 6.5% rise from the previous year. On average, milk availability per person was recorded at 394 grams per day. This marks a significant upward trend in dairy production since 1950–51, when the country produced only 17 million tonnes of milk (20th Livestock Census Report, 2019).

A significant amount of livestock resources all over the world is made by animal husbandry in India. The livestock sector backs up the socioeconomic growth as well as the national economy of the country. In addition to offering substantial potential and significant contributions to the agricultural sector in previous years, animal husbandry is providing great benefits in regard to production, export and value addition (Gamit et al., 2021). One of the key tests is to improve livestock productivity. 50% of the global average, which is 1172 kg, is contributed by the average annual milk yield of Indian cattle.

Recurrent occurrences of illnesses like Foot-and-Mouth Disease (FMD), Black Quarter (BQ), and Influenza continue to pose serious threats to animal health, often leading to decreased productivity. A large part of greenhouse gas emissions is contributed by large populations of ruminants. There has been a successful yet limited extent to the crossbreeding of indigenous species with exotic ones in order to improve the genetic potential of distinct species (Gamit et al., 2021). Limited services associated with Artificial insemination lead to deficiencies in quality germplasm, technical manpower and infrastructure with a poor rate of conception post artificial insemination have been a major limitation in livestock production for Indian farmers.

Despite notable progress in milk and other livestock outputs, India contributes less than 1% to global trade in this sector—a concern that warrants immediate attention. To compete internationally, it is essential to adopt scientific approaches in every aspect of livestock management, including animal care, nutrition, breeding, and health practices. Emphasis should also be placed on enhancing processing technologies and expanding the range of value-added livestock products (Singh, 2013). And in order to bring this shift, there is a need to determine the challenges that limit Indian agriculture and various farming practices.

1.7.3 Challenges in Indian Agriculture and Dairy Farming

Important considerations about sustainable agricultural practices include Biosecurity measures, health management, feeding strategies etc. One of the key challenges to food security linked to intensive livestock farming is the practice of housing animals in high-density environments. When animals are kept in close proximity, the chances of disease transmission significantly increase. In such intensive systems, livestock from various regions are brought together in centralized locations like barns or feedlots. This setup can introduce pathogens from one area into the entire production chain, allowing infections to spread rapidly among the animals. To control and limit the presence of these pathogens, disinfectants or biocides are often applied. However, it's crucial to use these substances carefully to avoid contaminating meat, milk, or the surrounding environment. Following proper biosecurity measures can prevent the transmission of diseases in livestock and can help maintain food security and production (Hoque et al., 2022).

Another significant factor that makes livestock animals vulnerable to the risk of diseases is transportation and changes in nutrition. The use of various antibiotics to treat infections among livestock promotes resistance and acts as a hindrance in the treatment of any disease. Vaccines are employed as an alternative to antibiotics, but their effectiveness depends on the animal's digestive health remaining intact. Therefore, maintaining proper nutrition and minimizing stress is essential to strengthen the animal's immune system and prevent the spread of diseases across species. The occurrence of various infectious diseases can also be reduced by following the rules and regulations associated with the transportation and feeding of livestock which can help promote the production and food safety (Hoque et al., 2022). To enhance the nutritional status and reduce the release of harmful pathogens and byproducts, it is necessary to ensure the feeding strategies for livestock. Balanced nutrition should be followed as a feeding strategy which can help improve the production and immunity of the livestock animal (Hoque et al., 2022).

An increase in livestock density leads to an increase in livestock production but causes an increase in the number of pathogens. Poor waste management strategies can cause soil, water and feed contamination. Hence, it is very necessary to properly manage livestock waste to resist microbial epidemic in the production system (Hoque et al., 2022). The pathogen overload is increased due to the taking of livestock from a large geographical area to a single place. A systematic preventive approach i.e., Hazard exploration and critical control point (HACCP) can help maintain food safety in livestock production processes from physical, chemical and biological contaminants that can make the end product contaminated and unsafe. This approach helps in the development of measures to reduce the risk to a safer level. It is important to incorporate HACCP during the meat and slaughter processing. These regulations are tailored to ensure consistent food safety standards globally while remaining flexible enough to suit regional livestock practices. The primary goal of food safety guidelines should be to safeguard public health, grounded in scientific evidence, rather than being driven by international trade demands or market pressures (Hoque et al., 2022).

Raising awareness about proper food safety habits is essential, especially since a significant portion of health issues—nearly 30 to 40%—originate within households. It's equally vital to inform the public about the potential health advantages and risks linked to the consumption of dairy and meat products. People should also be knowledgeable about how different methods of livestock production affect the environment. Efforts like social media outreach and educational extension programs are effective tools in spreading awareness, helping communities understand both food hygiene and the ecological implications of various production systems (Hoque et al., 2022).

There are various challenges associated with agriculture and other farming practices such as environmental, social, economic etc. Environmental issues primarily center around managing natural resources, tackling climate change, and cutting down greenhouse gas emissions. Livestock farming alone contributes approximately 14.5% to the total human-caused greenhouse gas emissions each year. There are noticeable differences in the farming systems and livestock species, with higher production generally providing fewer emissions per product generated. However, intensive systems emit less greenhouse emissions when compared to extensive systems. Proper animal health and better nutrition management can help improve productivity and biodiversity, along with reducing the emissions of greenhouse gases (Gerosa and Skoet, 2013). Economic challenges associated with agriculture and poultry/dairy farming are generally related to markets, trade and less investment in small-scale farms. The accessibility and functionality of livestock markets including livestock as well as their products, are very crucial for food security. The main reason behind poorly developed markets is poor supply chains and information gaps, poorly constructed trade policies and taxes, and the non-pricing of negative environmental and social externalities. Trade-related concerns encompass the transmission of diseases through livestock and agricultural products, implications for animal health and the environment, and challenges stemming from unequal competition due to subsidized imports. Additionally, there are economic debates surrounding the pros and cons of integrating foreign trade with national food security, as well as inconsistencies in country-specific regulations governing antimicrobial usage (Gerosa & Skoet, 2013).

Social challenges include gender discrimination and child labour. Generally, men are preferred for work by Pastoralist societies and among these societies, child labour is very common. The conditions for farmers are disappointing and have a low social status in intensive systems. Intensive livestock farming often relies heavily on migrant workers, who are frequently associated with unfavorable working conditions, a trend well documented by researchers (Gerosa and Skoet, 2013). In agriculture, health concerns are typically framed within the "One Health" approach, which considers both human and animal well-being. Animal diseases that impair productivity pose a serious risk, particularly in low-income nations, where the presence of such illnesses significantly contributes to poor livestock performance and reduced output. Low productivity is not only caused due to well-known infectious diseases but also by endemic diseases which directly affect animal health. Additionally, infectious diseases also directly affect human health apart from reducing production and productivity. The likelihood of zoonotic diseases spreading to humans rises when people and animals share close living spaces (Gerosa & Skoet, 2013).Apart from this, there are several views across countries regarding animal welfare, hence, it is a major challenge to restore an increase in productivity and welfare in the developing and intensive as well as uncontrolled livestock systems all over the globe (Gerosa and Skoet, 2013). However, in high-income countries, farmers are rapidly looking for animal-friendly livestock production.

1.7.4 Technological Advancements in the Field of Livestock Farming

In countries like India, agriculture lays the foundation for survival and food security. Beings living on the globe are mainly dependent on agri-based crops for their livelihood and survival (Upendra et al., 2020). India is an agricultural-dependent country with a majority of the population depending on agricultural products, influencing the country’s economy by varying annual crop yields of agricultural practices. A significant increase in crop production can be achieved by expanding the area of land suitable for cultivating a particular crop and minimizing losses through efficient agricultural methods. This involves careful management of key farming elements such as the appropriate type and amount of fertilizers, optimal water use, selection of high-quality seeds, and effective strategies to reduce both biotic stresses like pests and weeds and abiotic stresses such as unfavorable environmental conditions (Mariani & Ferrante, 2017). Some conventional and manual agricultural methods such as manual removal of contaminants and weeds and physical crop inspection are not very effective and have limitations when considering their support towards increasing crop yield (Abouziena and Haggag, 2016). In contrast, using sensors in agricultural practices allows for a more precise and scientific understanding of the specific needs of a crop under given conditions (Ramesh & Vardhan, 2013).

Digital agriculture is the utilization and integration of latest technologies into one system, enabling farmers within the agriculture value chain to improve production. Unlike traditional methods, automated farming allows cultivators to monitor and manage their agricultural activities more efficiently and in real time. The integration of digital tools in agriculture significantly contributes to improving crop productivity by equipping farmers with the insights needed to adopt more effective farming techniques (Upendra et al., 2020). Through the use of an interactive user interface, digital agriculture creates a platform for farmers to exchange ideas, learn about innovative cultivation methods practiced globally for specific crops, and access technological updates and entrepreneurial knowledge that can transform farming into a profitable and sustainable enterprise (Upendra et al., 2020). Agricultural automation systems include field machinery, greenhouse automation, irrigation systems, animal automation systems, and automation of fruit production systems which help in achieving enhanced crop yields (Edan et al., 2009).

A notable innovation in agriculture is the adoption of smart farming, which integrates information and communication technologies (ICT) into the cyber-physical management of farms (Babu and Babu, 2016). This method signals the onset of a Third Green Revolution through the digital transformation of agricultural systems. In the Indian context, there is a pressing need to transition from traditional agricultural methods to tech-driven smart farming models to ensure both sustainability and profitability. Also known as the Internet of Agricultural Things (IoAT), smart farming leverages ICT to monitor and manage various elements of farm operations, enabling farmers to optimize their practices with minimal labor and reduced costs, thereby boosting efficiency and yields (Upendra et al., 2020). The advantages of IoAT are wide-ranging—it supports real-time monitoring through sensors, remote supervision of crops, precise mapping of resources, climate tracking and forecasting, regulated use of agrochemicals, and accurate prediction of harvest outcomes (Jayaraman et al., 2016).

With the growing population and limited agricultural land, it becomes essential to minimize food and product wastage by enhancing food security through the implementation of automated supply chain systems. Today, automation plays a vital role throughout every phase of farming—from selecting high-quality seeds and planting them, to nurturing young plants, protecting crops from pests, and ensuring they receive the right amount of water and nutrients. These measures are essential for reducing crop loss and boosting overall yield (Upendra et al., 2020). Other applications of automation are processing of collected crops, post-harvest collection of crops, controlled and effective harvesting methods to decrease crop wastage, and transportation for marketing. Implementing automated food chain systems to enhance safety not only boosts business opportunities for the industry but also builds trust among farmers, increases their confidence, and draws more consumers to their farming practices.

One of the significant innovations in modern farming is the integration of big data analytics, which plays a vital role in addressing challenges within the food supply chain by working in conjunction with Application Programming Interfaces (APIs). This approach enhances agriculture by demonstrating the benefits of adopting best farming practices, encouraging data-driven investments, applying precision agriculture techniques on the ground, streamlining the food supply process, and automating operations to boost agricultural profitability. (Tsiolias et al., 2015). Data mining tools are supporting Decision Support Systems (DSS) in agricultural practices, with an aim to extract information from currently existing data sets and transform those information sets using specific tools to a unique format that can help easily understand the information and can be utilized for further advanced purposes (Upendra et al., 2020). Data mining helps in determining and studying the soil fertility and enabling farmers to make a decision to sow particular crops which results in better crop yield. Data mining tools such as GPS, k-means approach, SVMs, and K-nearest fertilize method are used to study the characteristics of soil, factors influencing the crop yield and pollution present in the atmosphere. Soil tests are done and suitable fertilizers are determined on the basis of the data available with reference to the composition of the soil, which helps the farmers to use a suitable fertilizer for particular crops during a specific season (Cambra Baseca et al., 2019).

One of the greatest concerns for agriculture is the changes in climatic conditions and their effects on human health and life. Big data analytics can be used to mine huge data sets of climate data focused on variations between the conventional mining climate data and big data approaches (Rani, 2017). One can analyses the data collected from rainfall and temperature of the last 5 years, with the help of big data analytics tools and get the exact difference in the climate of Indian Agriculture (Tripathi and Mishra, 2017). The use of sensors can help predict the effectiveness of certain fertilizers and seeds in different sections of the farm. Crop production can be influenced by various economic, biological and seasonal factors but undetermined changes in these factors can cause loss to farmers (Dhivya et al., 2017). To minimize crop damage and increase the yield of crops it is necessary to develop solutions for crop protection and weed control. New advancements are needed to use the existing data for predicting the occurrence of pests, diseases and weeds (Van Evert et al., 2017). A technique known as the Integrated Crop Management System (ICM), balances the necessities of developing a profitable agri-based business with accountability towards the environment. It includes practices that help reduce waste and pollution and boost energy efficiency (Upendra et al., 2020).

The application of modern technologies in farming has introduced various methods to enhance both the quality and quantity of crop production. Innovations such as digital farming, data-driven yield analysis, and precision agriculture have revolutionized the sector. Although a large segment of India’s population is engaged in agriculture, a noticeable disconnect still exists between technological advancements and their adoption by farmers. While the government continues to roll out supportive initiatives, there remains a significant need for simple, user-friendly advisory tools that guide farmers in making informed decisions—particularly regarding crop sowing (Upendra et al., 2020). Moreover, the integration of these technologies throughout different stages of crop development can lead to improved yields and cost efficiency for cultivators.

CHAPTER II

REVIEW OF THE LITERATURE

2.1 **Introduction**

A analytic review of literature forms an important foundational understanding of the existing body of knowledge pertinent to sustainable feed production for poultry and cattle farmers in India. The literature is reviewed to elucidate gaps and opportunities by synthesizing insights from past research, industry reports, and policy documents. Sustainable feed production is an important component of livestock farming that directs productivity, farmer livelihoods, and environmental outcomes. Existing research focuses on cost-effective feed management and innovation of feed technology and the incorporation of locally available resources for overcoming scarcity and feed production-related challenges. Existing national body publications on policy initiatives, industry trends, and importance of cooperative models in improving the feed supply chain have been brought out by the National Dairy Development Board and the Indian Dairy Association. Global research highlights the impact of climate change and resource constraints on livestock feed systems, which requires adaptive strategies.

2.2 Inclusion Criteria

This study includes government reports, peer-reviewed journal articles, and policy documents published between 2000 and 2025 that critically examine challenges in poultry and cattle farming, particularly in India. Studies were selected based on their relevance to feed production, breeding, veterinary services, technology adoption, and policy evaluation. Only empirical and theoretical works with a clear methodological framework and data-driven conclusions were included. Critical analysis was conducted to assess the validity, reliability, and applicability of findings. Literature was prioritized if it addressed sustainable practices, government interventions, and socio-economic impacts on livestock farmers in rural and semi-urban contexts.

2.3 Organizing Themes

2.3.1 Theoretical Overview

Livestock plays a significant role in providing protein to people, accounting for approximately one-third of their dietary intake. Particularly for impoverished individuals, animal-source food, including dairy products, is crucial for obtaining the necessary nutrients for cognitive and physical development (Randolph et al., 2007). A significant proportion of the global population, approximately half, lives in rural areas within developing nations, where smallholder farmers play a vital role in producing over half of the consumed food. Smallholder farming systems heavily rely on livestock as a crucial element. In many developing countries, livestock accounts for nearly 40% of the agricultural GDP (Steinfeld, 2006), and in some cases, this percentage exceeds 85% (FAOSTAT). Smallholders derive numerous benefits from livestock rearing, as it provides them with resilient livelihoods, thereby controlling poverty and food insecurity. Overall, livestock plays a pivotal role in the livelihoods of 75% of rural inhabitants and 25% of urban dwellers, and can even contribute up to 33% of household income (Nabarro & Wannous, 2014).

As individuals experience higher levels of prosperity, their consumption of animal-source foods tends to rise. The majority of population growth is concentrated in developing countries. In recent decades, there has been a notable growth in the consumption of animal meat in developing nations, growing at an approximate annual rate of 5%. Similarly, milk consumption has witnessed a growth rate of nearly 4% per year. This consumption trend has been particularly driven by elevated demand in the "People's Republic of China and Brazil" (Steinfeld & Chilonda, 2006). In the future, other developing regions that are undergoing economic expansion are expected to witness similar growth in meat consumption. Projections suggest that world meat production from animals will increase from "229 million tonnes in 1999/2001 to 465 million tonnes in 2050" (Robinson & Pozzi, 2011). The rate of increase in developing countries is anticipated to be substantial. Furthermore, milk output is projected to rise from "580 to 1,043 million tonnes by 2050" (Steinfeld, 2006).

In recent years, the poultry farming industry has experienced significant growth, becoming a major driving force in the livestock sector (Steinfeld & Chilonda, 2006). Global poultry production has consistently shown an annual growth rate surpassing 5% since the 1960s. Poultry now accounts for 30% of overall meat production globally, a significant increase from the 15% reported in 1960 (Steinfeld & Chilonda, 2006). While pigs have also contributed to the expansion of the livestock sector and overall meat consumption, there has been a decline in the consumption of meat from ruminant animals (Steinfeld & Chilonda, 2006). It is crucial to address the ecological challenges associated with the rapid growth of livestock production. Steinfeld et al. emphasize the need to reduce the ecological costs per unit of livestock production by 50% in order to mitigate further environmental degradation (Steinfeld, 2006). The livestock industry plays a major role in harming the environment, accounting for roughly 12% to 18% of greenhouse gases generated by human activity. It contributes to about 65% of nitrous oxide emissions linked to human actions—a gas nearly 296 times more potent than carbon dioxide in terms of global warming impact. A large share of these harmful emissions comes specifically from livestock waste (Nabarro & Wannous, 2014).

Animal farming plays a major role in methane release, accounting for about 37% of emissions linked to human activity. Methane is a potent greenhouse gas, with a global warming potential that is 23 times greater than that of carbon dioxide. In addition to greenhouse gas emissions, livestock production also has detrimental effects on land quality and water availability. Approximately 20% of the world's rangelands have experienced degradation due to livestock activities in the past decade. Livestock agriculture utilizes “15% of the water used for agriculture”, leading to ground water pollution, and poses a threat to biodiversity in 306 out of 825 ecosystems globally (Steinfeld, 2006). One specific challenge in livestock operations is associated with "free-range production systems”, which can present difficulties in protecting livestock from diseases. These systems often involve limited resource inputs, and small-scale farmers face obstacles in accessing integrated animal health management. Domestic Chicken production systems are categorized into different sectors based on scale and biosecurity levels, including “large-scale enclosed operations with moderate biosecurity (sector 2), small-scale free-range operations (sector 4), large-scale operations with limited biosecurity (sector 3), and large-scale enclosed bio-secure operations (sector 1)” (FAO, 2004). Ensuring powerful biosecurity measures in sectors 3 and 4 operations poses challenges for farmers. While expanding livestock production can bring nutritional and economic benefits to small-scale producers, they and their communities are more susceptible to animal and zoonotic diseases due to relatively lower biosecurity measures in these sectors.

Impoverished populations, especially those who are malnourished, face heightened vulnerability to diseases. In small-scale farming communities, livestock serves as a key component by supplying nutrient-rich animal-based foods, which are especially important for the health and nutrition of low-income populations. As economic conditions improve, meat consumption tends to rise. The main challenge is to ensure that smallholder farmers and underprivileged groups are able to take advantage of this growing demand. The implementation of policies becomes imperative to provide incentives and establish regulatory frameworks that enable effective livestock management within these communities. These policies should focus on increasing income while ensuring biosecurity and safety throughout the production, processing, and marketing of animal-source foods (Nabarro & Wannous, 2014). In many developing nations, women play a vital role in managing and caring for livestock. Providing women with improved access to essential resources and support services could significantly reduce global malnutrition—by approximately 100 to 150 million people (FAO, 2011). This holds particular significance in the livestock sector, where women predominantly manage tasks such as caring for animals, feeding them, and preserving livestock diversity. By enhancing women's involvement and support in livestock activities, the overall welfare and nutritional status of communities can be significantly improved.

According to a recent study conducted by the Food and Agriculture Organization of the United Nations (FAO), empowering women is crucial for the preservation of specific livestock breeds. Additionally, women are more vulnerable to zoonotic diseases due to their increased exposure and potential susceptibility (FAO, 2012). Unregulated growth in livestock production can lead to various adverse consequences, including environmental degradation caused by livestock, their contribution to global warming, public health risks, and a higher likelihood of zoonotic diseases. These challenges align with the rising public distress regarding the prosperity of meat-producing animals and the ambience in which they are raised. Governments must consider all these factors when formulating policies for the expansion of the livestock sector. These strategies must focus on ensuring efficient oversight of livestock farming, as well as the handling and distribution of products derived from animals. It is crucial to address issues such as ensuring secure land and water tenure, making informed decisions regarding alternative land uses, and ensuring the availability of essential services and goods, including livestock extension services and comprehensive veterinary care.

Livestock can serve as a source of diseases that can affect humans, known as zoonotic diseases. The transmission of pathogens between different species, including domestic animals, wild animals, and humans, contributes to the emergence of these diseases. Multiple factors influence the occurrence of zoonotic diseases, such as livestock production practices, food preparation methods, societal context, and specific ecosystems where interactions occur. The movement of people, animals, disease-causing agents, and insect vectors significantly impacts the epidemiology of zoonotic diseases, particularly when wildlife is involved. Human activities, such as changes in behaviour and modifications to natural habitats due to population growth and encroachment on wildlife habitats, also play a role in this dynamic (Nabarro & Wannous, 2014). Historically, the threat of diseases has influenced patterns of human travel and commerce, prompting the creation of public health strategies to reduce exposure and lessen impacts. Certain illnesses—whether they originate from animals or not—and their carriers can disrupt livestock productivity in particular environments. As a result, some nations have established wildlife reserves, not only for conservation but also because local disease presence makes the land unsuitable for raising livestock. Additionally, the movement of wild species, such as migratory birds, along with animals displaced by human activities, can contribute to shifting patterns of disease transmission (Kruse et al., 2004; Patz et al., 2003).

The level of disease exposure risk is closely associated with the ability of livestock rearers to implement effective biosecurity measures. These measures are crucial for preserving livestock health and preventing the initiation and extent of pathogens that can be transmitted from animals to humans. Implementing strong biosecurity protocols is crucial for controlling a wide range of diseases. This includes not only established zoonotic illnesses like bovine tuberculosis and brucellosis but also newer threats such as SARS and emerging strains of influenza. Effective biosecurity is also vital for containing cross-border animal diseases like Rift Valley fever and trypanosomiasis, along with foodborne infections. For nearly one billion people in low-income regions who depend on livestock for survival, zoonotic diseases present a serious threat (Nabarro & Wannous, 2014). These illnesses are responsible for approximately a billion human infections and millions of fatalities annually (Karesh et al., 2012).

Wildlife plays a crucial role as a reservoir of infectious diseases that have the potential to be transmitted to humans. Nearly 60% of new infectious diseases in humans are transmitted from animals, and about 70% of these are linked to wildlife sources (Taylor et al., 2001). In various parts of the world, growing human settlements and developmental activities have increased contact among people, domestic livestock, and wild animals. Activities such as deforestation, reforestation, and habitat changes have led to increased overlap and contact between humans, domestic animals, and wildlife (Kruse et al., 2004). Recreational pursuits like hiking, hunting, and camping also expose individuals to closer proximity to wildlife, thereby increasing the risk of acquiring zoonotic diseases. The consumption of wildlife, such as bushmeat, can pose dangers to those involved in its preparation or consumption. Reducing the threat of infectious diseases in livestock requires strong biosecurity protocols at every stage of the animal production and distribution process—this includes farms, transport systems, collection centers, and marketplaces. When these precautions are lacking, livestock operations become more susceptible to the emergence and spread of diseases, including those that may stem from wildlife (Nabarro & Wannous, 2014). Moreover, weak biosecurity can also lead to the reverse transmission of harmful pathogens from domesticated animals back to wild species, potentially causing serious ecological impacts.

2.3.2 Theoretical Perspective on the Challenges Faced by Poultry and Cattle Farmers

Developing countries encounter several challenges in the production and success of organic products. One significant hurdle is the limited knowledge and expertise in organic farming practices and production methods (Setboonsarng, 2006). Technical support in many developing countries mainly focuses on technologies that aim to increase productivity per unit of input and time. Knowledge about organic livestock farming is typically concentrated among private companies with access to export and minimal local markets. Another constraint is the lack of market information, including identifying suitable products for cultivation, selecting distribution channels and markets, understanding competition, and ensuring market access (Wolde & Tamir, 2016). Despite growing awareness among the population in developing countries regarding the health and environmental risks associated with inorganic agricultural products, there is a lack of comprehensive promotion highlighting the negative impacts of such products and the adoption of organic alternatives. Moreover, many governments in developing countries continue to prioritize conventional production systems, which hampers consumer awareness about the availability of organic agricultural products.

Organic food production is governed by rigorous regulations, particularly concerning certification. In some countries, farmers must wait for a period of two to three years after transitioning to organic management before their land and livestock can be certified as organic. This waiting period is deemed necessary to ensure the elimination of any chemical residues (Karim & Majdouline, 2006). Organic farming is primarily practised on a smaller scale due to its intensive management requirements. One of the challenges faced by organic farming is the increased need for labour input. Various studies indicate that the higher labour requirement in organic farming is a result of manual and mechanical tasks necessary for crop growth. Additionally, the process of preparing organic produce for sale, both on the farm and in the market, demands additional labour on organic farms (Patric & Alain, 1999). Consequently, this labour-intensive nature could pose a challenge for organic livestock farms, particularly as there is a growing trend of the rural workforce migrating to urban areas in forage of better wages.

The lack of clarity and understanding surrounding organic farming continues to impede its progress. Consumers often face challenges in discerning the specific characteristics and limitations of organic farming. This confusion arises from the existence of various "schools" or philosophies within the organic movement, inconsistent terminology, product presentation, and a tendency to blur the boundaries between concepts like organic, natural, and wholesome. Moreover, instances of fraudulent labelling and falsely claiming organic methods have exacerbated the situation (Bello, 2008). As income levels rise, urbanization increases, and there is a growing demand for animal products, it is expected that organic livestock products will gain access to profitable local markets. However, this also creates an opportunity for deceptive labelling practices due to the market's preference for organic livestock products and the information gap surrounding such products.

Organic research follows a decentralized and farm-based participatory approach, which incorporates local knowledge and traditional practices. It prioritizes public goods, resources, and tools that are not easily patentable. Consequently, organic farming receives relatively less investment from private origin compared to conventional and biotechnological methods (Parrott & Marsden, 2002). The practical implementation of organic farming presents several challenges. In regions where agroecology is not well established, such as areas dominated by industrialization and monoculture, there is a scarcity of land and manure. This often leads farm owners to adopt practices like zero grazing and confined systems for livestock husbandry. Another challenge relates to the overall farming conditions and the organization of global food distribution systems. This includes factors such as the transportation of live animals, the trading and transport of animal feed across the world, and the development of infrastructure to accommodate large herds (Vaars & Alrøe, 2012).

The media extensively covers the well-known environmental, economic, and social challenges that humanity faces. These challenges are often portrayed in a dramatic manner, highlighting the unprecedented turmoil and changes required for society to ensure its survival and prosperity in the 21st century. The ongoing environmental crisis has intensified concerns about our ability to maintain productivity while addressing both immediate and future challenges. Climate change and rising global temperatures are projected to interfere with natural vegetation cycles and influence the biological functions of livestock, leading to initiatives aimed at reducing greenhouse gas emissions (IPCC, 2010). Additionally, there is growing awareness that climate-related changes—such as shifting rainfall patterns and the increasing occurrence of extreme weather events like droughts, floods, and hurricanes—pose serious risks to the health and well-being of both humans and animals (Peacock & Sherman, 2010). The environmental consequences of pesticide use on soil fertility and biodiversity also require a reduction in their application, which may have potential implications for agricultural productivity.

The long-term impacts of soil degradation, largely driven by aggressive mechanization and intensive farming that fueled consistent crop yield increases over the past 40 years, are now gaining recognition and being actively assessed (FAO, 2010). This degradation has triggered a decline in biodiversity and the loss of genetic resources, resulting in the disappearance of many plant and animal species and breeds. Out of approximately 6,300 identified livestock breeds, nearly 1,350 are either at risk of extinction or have already vanished. Notably, about 20% of sheep and goat breeds are facing critical endangerment, despite being known for their rich genetic diversity and environmental resilience (FAO, 2004). Additionally, desertification has emerged as a pressing environmental issue. According to Talbi et al. (2009), more than 250 million individuals are directly affected by desertification, while over a billion people across more than 100 nations—primarily among the world's poorest and most vulnerable communities—are at serious risk. Furthermore, water scarcity is increasingly emerging as a critical issue, as water is now recognized as a strategic resource. The conversion of large land areas for bioenergy production poses a risk to both food security and the environment (FAO, 2010).

Numerous social and economic challenges arise from the environmental issues mentioned earlier, as well as economic and energy-related concerns. The global population affected by chronic hunger exceeds one billion people, and this number may increase without effective solutions and decisions (Dubeuf, 2011). The Food and Agriculture Organization (FAO) highlights that insufficient investment in the agricultural division in many countries hinders agricultural growth and perpetuates hunger. The recent financial and economic crisis has worsened hunger levels, particularly among the poor, as it reduces or eliminates their sources of income necessary for survival. The competition for energy resources further complicates the situation by potentially limiting farmers' investment capacity, promoting the rapid conversion of land for biofuel production, or leading to the acquisition of land by foreign organizations or states (cases of which have been observed worldwide).

A report titled "Livestock's Long Shadow" was issued by the environment, livestock, and development (LEAD) team at FAO (Steinfeld et al., 2006). This report presented substantial evidence highlighting the negative environmental impact of livestock and related human activities. That said, later studies conducted by the LEAD team have offered a deeper and more well-rounded perspective on the environmental challenges linked to various types of livestock and methods of production. In arid regions, around 100 million people rely solely on grazing livestock for their livelihoods, and a similar number of people in other areas also depend on livestock for their sustenance.

Livestock can play a beneficial role in improving soil quality, vegetation cover, and biodiversity. They contribute to reducing biomass that can fuel bushfires, control shrub growth, aid in seed dispersal through hoof movement and manure deposition, and enhance plant species composition. Trampling by livestock can facilitate seed germination and disband hard soil crusts (Steinfeld et al., 2006; Peacock & Sherman, 2010). Additionally, grazing can help prevent fires in many cases. Goat and other small livestock farming systems, commonly found in rural areas as part of mixed farming or extensive/crop-based systems (Devendra, 2010), are particularly susceptible to these challenges. Most goat and small livestock farming practices involve low-input systems with minimal environmental impact. These systems also offer social benefits for rural populations in various countries and isolated regions, as they are less affected by economic fluctuations. Promoting the potential future contribution of goats and other small livestock, as emphasized by Devendra (2010) and other relevant studies, can help address emerging issues and concerns.

Addressing the difficulties faced by small farmers and the landless requires consideration of various policy elements, including “education, advocacy, empowerment, gender-focused actions, direct government interventions, supportive laws for micro-credits, and active involvement of non-governmental organizations (NGOs)”. However, the most critical aspect is investing in research and development (R&D). The main objective is to formulate policies that improve the livelihoods of small farmers, promote institutional engagement, invest in specific agroecosystems, and enhance productivity, technology application, and innovation through adaptive R&D. It is important to consider post-production systems, establish linkages, and facilitate market access. In the broader context of animal production and animal health research, (Herpin and Charley 2008) emphasized the need to address key global challenges related to climate change, sustainable development, biodiversity management, water quality, food safety, bioenergy and emerging diseases. They highlighted the increasing necessity to enhance worldwide food production in response to population growth. The changing status of animals and breeding management has placed animal production and its products at the centre of societal debates, underscoring the importance of addressing these research issues.

2.3.3 Theoretical Perspective on the Indian Livestock Industry

In 2011, India ranked sixth globally in chicken meat production, according to the rankings reported by FAOSTAT (Foreign Agricultural Service, Official USDA Estimates). By 2014, the average annual poultry meat consumption per person in India was anticipated to rise to 2.2 kilograms, with chicken emerging as the most favored source of non-vegetarian protein. According to Gandhi and Zhou (2010), India was witnessing a sharp rise in demand for animal-based food items, with estimated yearly growth rates of around 10.6% for milk, 7.4% for eggs, and 8.4% for meat. As per (Brown et al. 1999), rising incomes in low-income societies often lead individuals to diversify their diets by consuming more livestock products, aligning with Bennett's Law, which suggests that higher incomes result in more diversified and higher-quality food consumption.

Urbanization plays a crucial role in projecting future food demand as it influences caloric requirements, food availability, and consumption patterns, especially with access to a wider range of food options and a preference for processed foods (Dyson & Hanchate, 2000). Urbanization is closely linked to economic development and income growth, and it is a significant trend in developing nations. Therefore, any estimation of future food demand should consider the impact of urbanization to ensure comprehensive and accurate projections. Analysis of long-term food consumption data from the National Sample Survey (NSS) reveals that individual cereal consumption in India has been on a decline since the early 1970s (Chatterjee et al., 2006). This downward trend is mainly due to the increased availability and rising preference for diverse food options such as dairy products, meat, fish, eggs, fruits, and vegetables. These changes highlight a clear transformation in India's dietary habits, largely influenced by growing income levels and rapid urbanization, which are fueling a surge in demand for non-cereal foods. Notably, the responsiveness of rural household spending on animal-based food products is greater than that of urban households, suggesting that rising rural incomes will likely accelerate demand for livestock-based items. Moreover, expenditure on livestock foods tends to be more income-sensitive than other food categories, reflecting a broader transition in consumption behaviors and reinforcing the trend toward agricultural diversification.

India is currently undergoing significant economic reforms, similar to the changes that occurred in China over a decade ago (UN, 1996). In terms of milk production, India holds the position of being the largest producer, with an annual output exceeding 160 million tons. However, per capita, milk consumption in India stands at approximately 350 grams per day. With a population of over one billion, India showcases diverse food habits, cultures, traditions, and religions, resulting in notable regional variations across the country. In 2020, the total demand for fresh milk in India reached approximately 115.61 million tonnes. Additionally, the demand for mutton and goat meat amounted to 4.57 million tonnes, beef and buffalo meat reached 1.00 million tonnes, chicken accounted for 0.64 million tonnes, and eggs were at 31.47 billion in quantity. From 1993 to 2020, the demand for these products exhibited compound annual growth rates of 3.71% for milk, 8.42% for mutton and goat meat, 2.85% for buffalo and beef meat, 3.75% for chicken, and 4.70% for eggs. Among livestock products, the demand for mutton and goat meat is projected to experience faster growth, followed by eggs.

However, it is important to exercise caution when considering the projected surplus in milk production, as it may be an overestimation. To improve the accuracy of demand-supply projections, methodological innovations and data refinements are necessary. Several constraints hinder the growth and development of India's livestock industries. These include the decline in grazing lands due to overstocking and soil erosion. Additionally, there has been a decrease in the production of coarse grains in India (Nair, 1995). At the farm level, there is a noticeable lack of advanced knowledge and reliable diagnostic tools for identifying animal diseases. Additionally, the absence of well-structured market facilities and the unorganized nature of livestock trade hinder the sector's growth. Educational and research funding in agriculture often overlooks the livestock industry, further slowing its progress. Moreover, the lack of a unified national market leads to inconsistent pricing, and in some regions, government subsidies and price controls on milk disrupt efficient market operations.

Technological progress is a key factor in driving the livestock revolution, as reflected by high expenditure elasticities within the livestock sector and the diversification of Indian agriculture. To promote further development, it is essential to implement policies that focus on enhancing fodder supply, ensuring remunerative prices for livestock products, and investing in technology improvements, particularly in processing and value-addition within the livestock sector. These aspects require careful attention and consideration (Roy et al., 2021).

2.3.4 Theoretical Perspective on the Government Policies

Even today, livestock plays a crucial role in rural economies, with agriculture and animal husbandry intertwined since ancient times. Approximately 70% of people in rural areas rely on animal husbandry and agriculture, which form the foundation of the rural economy. The combination of crop production and livestock rearing allows for the fuller utilization of agricultural by-products, increases income and economy, and helps conserve soil fertility. Livestock is particularly important for small-scale farmers and landless labourers, providing employment opportunities and serving as a valuable source of supplementary income. Livestock plays a vital role in ensuring access to protein-rich, nutritious foods such as milk, meat, eggs, and various processed animal products, which are important for human health. Additionally, animal waste serves as an important organic input for farming, while dung and animal-driven labor continue to be crucial sources of energy in many rural communities (Satashia & Pundir, 2021). Beyond its economic contributions, livestock also holds deep social, cultural, and traditional value. For many low-income rural families, animals serve as a form of financial security, offering support in times of hardship. Furthermore, the sector supplies key raw materials like hides and skins, supporting the leather industry, which generates significant employment opportunities and contributes to exports. The Royal Commission on Agriculture (RCA) initiated efforts to formulate livestock development policies in 1928. The commission recognized the character of draught animals in Indian agriculture and acknowledged the challenges posed by excessive cattle numbers and feed scarcity. The RCA made a connection between the cycle of low-quality livestock, fodder scarcity, and the religious sentiments against cow slaughter in Hindu culture. The National Commission on Agriculture (NCA) conducted a comprehensive review of the livestock sector in 1976, focusing on the Fifth Five-Year Plan (1974-1979) (Ramamohana et al., 2020). The NCA Report extensively addressed the issues and prospects of animal husbandry and livestock production.

The First Five-Year Plan aimed to advance the livestock sector by prioritizing higher milk output, ensuring consistent milk supply to high-demand urban regions, and improving the quality and accessibility of draught animals for farming. To meet these goals, efforts were made to enhance native cow breeds through selective breeding, while crossbreeding with indigenous high-yielding varieties was promoted to improve milk productivity. Similarly, draught animals were selectively bred to create efficient dual-purpose animals (Yadav et al., 2021). The plan also identified critical issues such as limited fodder availability, overpopulation of livestock, and challenges related to keeping cattle in urban areas. One of the major initiatives under this plan was the Key Village Scheme, which aimed to increase milk production and ease fodder shortages (Ramamohana et al., 2020). Additional interventions included the castration of unproductive bulls and the adoption of the Livestock Improvement Act by several states to control livestock numbers and ensure better breeding practices. Artificial insemination was also introduced as a method to accelerate genetic improvement in livestock.

Although animal diseases were recognized as significant hindrances to productivity improvement in the First Five-Year Plan, no substantial measures were implemented to control these diseases except for speculation in veterinary hospitals and dispensaries. To address milk supply in urban areas, the government established dairy plants responsible for milk procurement, processing, and marketing. The issue of urban livestock was to be resolved through the creation of peri-urban cooperatives supporting milk production and provide to government-owned dairies. The Second Five-Year Plan largely maintained the same policies and strategies without significant changes. Together the First and Second Five-Year Plans failed to incorporate a meaningful scheme for breed improvement or efforts to enhance the work output of draught animals (Ramamohana et al., 2020). The Third Five-Year Plan continued the strategies and policies of the previous plans but acknowledged the necessity of implementing a comprehensive policy for breeding cattle to achieve increased milk production.

During the Third Plan, limited cross-breeding practices were initiated, but their success was limited, particularly due to fodder availability issues. The defeat of urban milk schemes were also recognized, highlighting the required for a greater focus on rural-oriented milk production. During the Third Five-Year Plan, key policies focused on setting up feed mills to ensure a consistent supply of animal feed and encouraged domestic production of equipment and machinery for dairy processing (Ramamohana et al., 2020). There was also growing recognition of the economic value of animal by-products like hides, skins, and carcass materials. In the Fourth Plan, major policy changes were introduced in the livestock sector. The ‘key village’ initiative expanded into comprehensive cattle development projects, emerging as a central government strategy for cattle improvement. Additionally, the inefficiencies observed in state-led dairy programs prompted a policy redirection toward enhancing milk production in rural milk-producing zones and transporting processed milk to cities to meet rising urban demand. This new approach was formalized with the creation of the National Dairy Development Board and carried forward through the launch of Operation Flood I (Bayan, 2020). Importing commodities as substitutes for domestic milk procurement was prevalent during this time, with government dairies relying on significant amounts of imported powder annually, primarily reconstituted milk produced in government-owned plants.

Operation Flood aimed to eliminate the need for commodity aid by utilizing gift commodities. As a result, the stagnant milk production in the country since independence experienced a significant shift. The growth of milk production, which was 3 million tonnes between 1947 and 1969, accelerated to 22 million tonnes in 1972 and reached 44 million tonnes in 1985. The national policy of cross-breeding cattle gained momentum and economic significance, particularly through the cooperative network established under Operation Flood, which provided market stimulus and price incentives (Ramamohana et al., 2020). The prices offered by cooperatives effectively served as support prices for milk, establishing milk as a marketable commodity. Buffaloes also emerged as a primary cornerstone of the Indian dairy industry.

During the Fourth Five-Year Plan, a dedicated approach to dairy development was launched, including the creation of the 'National Milk Grid.' This strategy was designed to tackle the challenges of uneven milk availability across seasons and regions. It also focused on creating facilities for transporting, storing, and stockpiling milk and milk products throughout the nation. By offering price stability to farmers through village-level cooperatives, the policy helped manage supply-demand gaps, supported milk reserves, and allowed market regulation as needed by both public and private entities (Yadav et al., 2021). This period also marked notable advancement in the cattle feed production and dairy equipment manufacturing industries, signaling progress in the broader dairy sector. By the mid-1980s, the Indian manufacturing industry had the capability to meet approximately 75-80% of the industry's machinery requirements, except for advanced equipment (Ramamohana et al., 2020).

The Fifth, Sixth and Seventh Plans were dominated by the Operation Flood Project, which became the focal point of policy considerations for two decades, from 1970 to 1990 (Ramamohana et al., 2020). However, the importance of draught animals in the Indian farming system was overlooked in the Five-Year Plans, including the Royal Commission on Agriculture (RCA) and the National Commission on Agriculture (NCA). The Eighth Plan was the first to document an official policy statement addressing the improvement of drought animals and their relevance to the overall bovine population (Bayan, 2020).

Concrete strategies to implement and capitalize on this policy perception have yet to materialize. Buffaloes, despite their significance in milk production, did not receive substantial attention in successive plans. The preference for cows may be attributed to their potential as work animals through the provision of male calves (Ramamohana et al., 2020). Initiatives for progeny testing of both cattle and buffaloes were launched during the Third Plan period, but their success was limited due to the lack of connection between these programs and field artificial insemination initiatives for buffaloes. Fodder development remained neglected even during the Seventh Plan, and the severe drought experienced from 1985 to 1987 highlighted the urgent need for alternative strategies to feed livestock (Ramamohana et al., 2020).

Regarding animal disease control, the Eighth Plan focused on expanding the coverage and capabilities of State Departments of Animal Husbandry, with a greater emphasis on curative therapy rather than prevention and control. During the Seventh and Eighth Five-Year Plans, efforts were made to improve disease prevention and control, including programs like the National Rinderpest Eradication Programme and enhanced regional collaboration for disease management. In the subsequent Ninth and Tenth Plans, animal husbandry and dairy development were identified as key priorities, aiming to boost income and job creation, improve access to animal-based proteins in diets, and produce surplus goods suitable for export. Efforts will revolve around addressing policy distortions, establishing participatory institutions, creating an environment for farmers to invest in livestock sector productivity, and developing effective regulatory institutions (Ramamohana et al., 2020). These efforts will form the basis for growth and progress in animal husbandry and dairying during the Ninth and Tenth Plans.

2.3.5 Theoretical perspective on strategies adopted in Poultry and cattle farming

By 2050, the world's population is expected to exceed 9 billion, marking an increase of roughly 2 billion people from today's figures (FAO, 2011; United Nations, 2019). This surge, combined with rapid development, is likely to drive a significant rise in the need for animal-based food products. In many developing countries, livestock remains a key contributor to food security, employment, and income generation. At the same time, consumers are becoming more mindful of the broader implications of animal agriculture, particularly regarding environmental impact, human health, and ethical treatment of animals (Ochs et al., 2018). As pressure mounts on natural resources like land and water, it becomes increasingly important for the livestock sector to adopt more efficient and sustainable production methods (Baldi & Gottardo, 2017). The European Union has committed to reaching climate neutrality by the year 2050. In response to shifting public values—especially among consumers—there is a growing demand for responsible research and innovative solutions that tackle the major challenges in livestock production through sustainable and circular strategies.

To meet the increasing global need for animal-based protein—while also addressing critical issues like public health, environmental concerns, and animal welfare—farmers and livestock experts are turning toward Precision Livestock Farming (PLF) to modernize and digitize traditional animal agriculture. In the last ten years, there have been considerable innovations in areas such as automated feeding, robotic milking, and smarter waste handling systems. These technologies focus on improving productivity by integrating tools and knowledge from genetics, animal breeding, nutrition, and instrumentation (Wurtz et al., 2019). Yet, despite these technological strides, some key obstacles remain. The push for higher livestock output often leads to dense and confined housing systems, which restrict farmers' ability to monitor animal health and behavior effectively (Helwatkar et al., 2014). Additionally, with climate change worsening, livestock are more susceptible to illness, heat stress, and other physiological challenges (Bernabucci, 2019). This has created an urgent need for early disease detection, understanding of transmission patterns, and implementation of preventive strategies to avoid significant economic impacts (Thornton, 2010). Altogether, these issues—combined with a rising demand for greater welfare, environmental responsibility, and system transparency—are accelerating the adoption of digital livestock management practices through PLF technologies (Vickers, 2017).

Precision livestock farming applies process engineering methods to automate animal husbandry, enabling farmers to effectively oversee the health and well-being of large groups of livestock. These technologies facilitate the timely detection of individual animal issues and even allow for the anticipation of potential problems based on historical data (Benjamin & Yik, 2019). Recent developments in precision livestock farming technologies encompass various aspects such as monitoring cattle behaviour, detecting vocalizations in pigs, identifying respiratory illnesses through cough monitoring in different species, and detecting bovine pregnancy through changes in body temperature (Vickers, 2017). By adopting precision livestock farming methods, farmers can closely track and control the spread of infectious diseases among animals, which in turn helps to improve the safety and supply of food (Neethirajan et al., 2018). These technologies are designed to promote better animal health and well-being, ensure food safety, and make more efficient use of available resources (Norton et al., 2019).

Biometric sensors are employed in livestock farming to track animals' physical and behavioral patterns, enabling farmers to monitor their health and overall well-being over time (Neethirajan et al., 2018). These sensors fall into two categories: invasive and non-invasive. Non-invasive types are typically installed within the barn environment and may include tools such as video surveillance systems and feeding sensors that help monitor food consumption and body weight of the animals. Sensors can also be integrated directly onto animals—for example, pedometers, GPS devices, and activity monitors based on MEMS (microelectromechanical systems)—to observe and track behavioral patterns (Helwatkar et al., 2014). Although less commonly applied in livestock, invasive sensors that are either implanted or ingested offer valuable insights into internal bodily functions. These include monitoring rumen activity, body temperature, and vaginal pressure, particularly in dairy cattle (Helwatkar et al., 2014). The use of biometric sensors in livestock farming is growing rapidly, as they allow for the efficient tracking of more animals without increasing physical handling or staffing needs. These tools provide consistent and accurate data on animal health and welfare (Neethirajan et al., 2018). The information gathered is stored in digital databases and analyzed using algorithms—step-by-step computational processes tailored to solve specific monitoring tasks.

Biometric sensors in livestock are designed to collect raw data and interpret it using advanced algorithms to derive meaningful biological insights. These tools can measure how long animals engage in certain behaviors throughout the day and track variations in their activity over set periods (Benjamin & Yik, 2019). Moreover, they can detect behavior patterns that fall outside normal thresholds and immediately alert farmers to potential issues. This early detection helps in timely health assessments and interventions to ensure animal well-being (Neethirajan et al., 2018). When combined with big data tools, artificial intelligence, and genomic bioinformatics, these systems can also help identify animals with beneficial traits, making them valuable for selective breeding initiatives (Ellen et al., 2019).

The integration of biometric and biological sensors in the cattle sector has greatly improved the ability to monitor animal welfare and automate routine management practices. These technologies offer valuable data related to animal health and productivity. Specifically, biometric sensors have proven useful in identifying and managing conditions like lameness, mastitis, cystic ovarian disorder, displaced abomasum, and ketosis. Furthermore, ongoing studies aim to automate the tracking of key productivity indicators such as physical activity, emotional well-being, estrus cycles, and milking patterns (Helwatkar et al., 2014). Cattle farming poses specific challenges for farmers, as individual animals represent a significant investment and various factors can influence the overall profitability of a herd. Accurate monitoring of fertility cycles, particularly estrus, in real-time is crucial for effective herd management. Furthermore, precise control over nutrition and energy intake is essential for maximizing milk production. Biometric sensors have shown promise in detecting estrus, with pedometers being successful in dairy cows (Helwatkar et al., 2014). According to a recent study by Rottgen et al. (2019), researchers explored the use of automated systems to detect and recognize vocal sounds from individual cows in a herd as a way to monitor estrus in dairy cattle. The findings demonstrated encouraging outcomes, with an 87% sensitivity rate and a 94% specificity rate.

Disease spread is a significant concern in poultry production due to the ease of pathogen transmission between birds and farms. Precise temperature control is essential in poultry farming to maintain the health of adult birds and create an optimal environment for chick embryonic development (Andrianov et al., 2020). The importance of real-time monitoring and immediate decision-making in poultry farming highlights the growing reliance on sensor-based technologies in Precision Livestock Farming (PLF). Various sensing tools and platforms used in PLF can track environmental temperatures within poultry houses and alert farmers when intervention is required. Temperature regulation is critical for embryo growth and is one of the main contributors to heat stress in broiler chickens (Bloch et al., 2020). Studies have shown that infrared thermometers provide precise readings of broiler body temperatures, often outperforming internal temperature logging devices (Bloch et al., 2020). Additionally, non-invasive heart rate sensors have been employed to assess incubation temperatures (Andrianov et al., 2020) and detect heart-related abnormalities in developing chicken embryos (Ghasemlounia et al., 2021). Moreover, mobile applications paired with appropriate sensors offer an accessible method for tracking embryo heart rates, allowing timely farmer intervention to avoid potential embryo losses during the incubation phase (Phuphanin et al., 2019).

Biometric and biosensor technologies play a key role in tracking the health and well-being of livestock, producing vast volumes of data in the process. To derive useful insights that support effective animal management, this data must be thoroughly processed and interpreted. As a result, there has been notable progress in the field of big data analytics, aimed at managing and evaluating large, complex datasets (Kunisch, 2016). Big data refers to datasets that are large in size, making visual inspection impractical due to the high number of rows and columns. Moreover, such datasets typically involve a large number of variables or features, making them complex and not ideal for conventional statistical approaches (Morota et al., 2018). The concept of big data is often characterized by the "4 Vs": volume, representing the immense scale of generated data; velocity, denoting the speed at which data is created and analyzed; variety, reflecting the diversity in data formats and sources; and veracity, stressing the significance of data reliability and the necessity for accurate validation and cleaning (Koltes et al., 2019).

Blockchain refers to a distributed or decentralized ledger that securely records encrypted transactions. Each time a transaction takes place, it creates a new node in real time, storing details specific to that transaction and adding it to the growing chain of blocks (Chattu et al., 2019). The four fundamental principles of blockchain technology are distribution, transparency, immutability, and democracy. In the context of livestock agriculture, these principles can be applied by assigning a unique identification to each animal on the farm, which remains with the animal throughout its lifespan. This unique ID enables the collection of data related to the farm(s) where the animal resided, transportation from the farm(s) to the slaughterhouse, veterinary checks at the slaughterhouse, post-slaughter quality inspections, meat product transportation, and details of packaging and retailing. Integrating blockchain technology into livestock farming brings numerous benefits, such as enabling decentralized and automated transactions that can enhance the efficiency of audit systems used by certification and regulatory bodies. It would also support seamless system integration, ensure well-maintained documentation of every stage in the animal’s journey from farm to consumption, and significantly improve traceability and openness within the livestock farming industry (Picchi et al., 2019).

Lately, the trust gap between producers and consumers in the agricultural sector has widened, largely due to rising expectations for openness about how food is produced. Blockchain technology offers a promising approach to bridge this gap by ensuring transparency at every stage of an animal's life cycle. This technology is especially useful in tracking and controlling disease outbreaks in livestock, including cases like Foot-and-Mouth disease, Avian flu, Mad Cow disease in Europe, and swine flu (H1N1) (Lin et al., 2018). It can also help address concerns related to the recent surge in salmonella outbreaks (Dyda et al., 2020). Consumers are becoming more conscious of the sustainability and ethical considerations associated with animal husbandry, and they demand transparency in animal-raising practices. Food safety is another significant concern, with the World Health Organization reporting a high number of food-related illnesses and deaths each year (World Health Organization, 2020). Blockchain can play a crucial role in identifying the origin of contaminated food, enhancing both transparency and responsibility across the livestock and agriculture sectors (Lin et al., 2018).

A key benefit of blockchain technology lies in its decentralized framework, which permits data sharing across multiple participants in a network, eliminating dependence on a central authority. In the event of a livestock disease outbreak, blockchain empowers farmers from different regions to securely log and retrieve outbreak-related data, thereby playing an active role in disease monitoring and prevention efforts on their farms (Chattu et al., 2019). As food supply chains become increasingly global, the need for animal products to meet international welfare and sustainability standards has grown. Verifying adherence to these standards becomes difficult when records are maintained through traditional paper-based methods or confined to isolated digital systems (Motta et al., 2020). Despite its importance, the livestock sector remains less digitally advanced than many other industries as of 2020, highlighting significant room for technological adoption and enhancement (Motta et al., 2020).

The digitalization of livestock agriculture and the integration of blockchain technology offers potential solutions to address the challenges related to disease outbreaks and food safety. It is essential to recognize that blockchain technology remains in its developmental phase when it comes to broad use within the food sector, and there is a scarcity of focused research evaluating its role in livestock farming (Neethirajan & Kemp, 2021). The involvement of bioengineers and data scientists is crucial in identifying the most appropriate blockchain solutions for specific livestock farming sectors by establishing relevant criteria and guidelines.

2.3.6 Operationalization of Theoretical Constructs

In quantitative research, operationalization is a vital aspect that involves the process of defining how to measure a phenomenon or concept that cannot be directly quantified. This concept is applicable to fundamental psychological constructs like motivation, well-being, and emotions, as well as seemingly tangible concepts such as health, intelligence, or learning progress. The core idea of operationalization is based on the belief that a theoretical concept under study can be identified through its measurable outcomes (Emmerich et al., 2016).

Operationalization involves the creation of indicators or items aimed at quantifying theoretical constructs. For example, when dealing with an intangible theoretical construct like socioeconomic status, which can be defined as the family income level, its operationalization can be achieved through an indicator that poses a question to respondents: "What is your annual family income?" Due to the inherent subjectivity and inherent imprecision associated with social science constructs, the measurement of the majority of these constructs (except a few demographic constructs like age, gender, education, and income) is typically conducted using multiple indicators. This approach enables us to assess the degree of agreement among these indicators as a measure of their precision (reliability).

Indicators operate within the realm of empirical observation, distinct from constructs that are established at a theoretical level of abstraction. The amalgamation of indicators at this empirical level to represent a specific construct is termed a variable. These variables can assume various roles, serving as independent, dependent, mediating, or moderating factors depending on their application within a research study. Indicators are categorized into two main types: reflective and formative. A reflective indicator mirrors an underlying construct. For example, if religiosity is conceptualized as a construct encompassing an individual's degree of religious devotion, attending religious services can serve as a reflective indicator of their religiosity. Conversely, a formative indicator contributes to or shapes an underlying construct. Such indicators often represent distinct dimensions of the construct being studied. If religiosity comprises dimensions like belief, devotion, and rituals, selected indicators for each dimension become formative indicators.

Conceptual frameworks have been developed to explore and answer the research questions: Research Question 1: What challenges and risks do poultry and livestock farmers encounter in relation to animal nutrition, breeding practices, health management, and access to veterinary care?

- **Resource Management:** Recently, the global concern over climate change has escalated. The transformation in climatic patterns is primarily attributed to the surge in the concentration of greenhouse gases (GHGs) within the atmosphere. Various aspects of livestock management—ranging from animal types, land use, feeding methods, digestion-related emissions, manure handling, to processing, slaughter techniques, and storage—play a significant role in the overall greenhouse gas emissions. The impending consequences of climate change are anticipated to exert influences across various dimensions, encompassing the quality of forage and feed, the availability of water resources, the productivity of livestock, reproductive processes, the calibre of livestock-derived products, and the prevalence of livestock ailments. To balance this growing demand with a sustainable supply, the formulation of precise strategies aimed at both adapting to and mitigating the repercussions of climate change is critical (Haldar et al., 2022).

- **Breeding Constructs:** The history of animal breeding in India is marked by its unique journey. With growing pressures on agricultural land and an increasing human population, the livestock and poultry sector has emerged as a promising contender in the food industry. However, the productivity of livestock remains notably low in the country. This can be attributed to a range of factors including the limited implementation of structured breeding programs, insufficient attention to nutritional needs, and the intricate interplay with socio-economic challenges. In order to address these issues, there is a pressing need for a localized approach to formulate breeding policies that directly address specific community needs. To ensure the success of such an approach, it is crucial to establish a consistent stream of investments (Gowane et al., 2019).

Research Question 2: Which existing government policies support poultry and cattle farmers, and what additional measures should be introduced to further benefit them?

- **Economic Constructs:** The process of agricultural commercialization and diversification refers to the steady shift from integrated farming systems toward more specialized ventures focused on crops, livestock, poultry, or aquaculture production. The adjustments in the range of products and the allocation of resources are primarily influenced by market dynamics during this transition. The shift toward market-oriented agricultural production is a natural outcome tied closely to economic development, increasing urbanization, and the movement of the workforce away from farming activities (Tomich et al., 2019).

- **Animal Welfare:** In Asia and the Far East, livestock frequently endures distress caused by malnutrition, excessive workloads, and mistreatment. During the slaughtering process, animals often experience rough handling and witness the slaughter of other animals, as the practice of stunning is not commonly employed. While the efforts of animal welfare organizations have successfully curtailed cruelty towards other creatures like elephants, horses, donkeys, bears, dogs, and animals in circuses, these accomplishments have been hard-won. Governments have initiated the formation of Animal Welfare Boards and the enactment of laws aimed at preventing animal cruelty. However, the impact of these measures remains limited due to financial constraints and a lack of personnel, which hinder the effective implementation of existing laws (Escobar et al., 2018).

Research Question 3: What methods are being used to raise awareness and introduce modern technologies in poultry and livestock farming?

- **Institutional Constructs:** The globalization of food markets is poised to profoundly impact India's livestock sector and the dependent households. This phenomenon presents an avenue to access international markets but comes with the condition of adhering to stringent food safety and quality standards. Simultaneously, persistent imbalances in global markets, while following a liberal domestic trade policy, could potentially result in an influx of imports, posing a direct threat to the livelihoods of numerous livestock producers. Therefore, a comprehensive assessment of the effects of both globalization and domestic trade policies on livestock producers, particularly small-scale ones, is necessary. It is essential to recommend suitable technological, institutional, and policy measures that can strategically transform these challenges into opportunities (Abu Hatab et al., 2019).

2.4 Research Gap

While significant advancements have been made in precision livestock farming (PLF) technologies, such as biometric sensors, automated feeding systems, and blockchain for traceability (Benjamin and Yik, 2019; Neethirajan et al., 2018; Chattu et al., 2019), existing literature lacks a comprehensive analysis of how these innovations directly impact small-scale poultry and dairy farmers in India, especially in rural and semi-urban regions. Most studies focus on technological capabilities rather than the socioeconomic constraints these farmers face, including limited access to veterinary care, inadequate feed quality, and insufficient training (Helwatkar et al., 2014; Bernabucci, 2019). Moreover, while policy frameworks and sustainability strategies are discussed broadly, their real-world effectiveness and integration at the grassroots level remain underexplored (Thornton, 2010; Vickers, 2017). There is also a lack of empirical data connecting government policies and the practical adoption of PLF technologies with measurable outcomes in productivity, animal welfare, and economic improvement. This study addresses these gaps by evaluating the implementation, effectiveness, and policy support surrounding modern livestock technologies in the Indian context.

2.5. Summary

The focus of this research is to tackle the difficulties and uncertainties associated with sustainable feed production for poultry and cattle farmers in India. The objective is to investigate strategies and solutions that can assist farmers in overcoming these uncertainties and implementing sustainable feed production practices. The research seeks to provide valuable insights into sustainable feed production methods, specifically tailored to the distinctive circumstances of poultry and cattle farming in India. By comprehending the challenges and uncertainties involved, the study aims to offer practical recommendations and guidelines to aid farmers in adopting sustainable feed production practices. Ultimately, the goal is to enhance environmental sustainability, promote animal welfare, and improve overall agricultural productivity in India.

CHAPTER III

RESEARCH METHODOLOGY

3.1 Introduction

This chapter presents the approach used to investigate the issues and potential in sustainable feed production for poultry and cattle farmers in India. Due to the multifaceted nature of the topic, the study employed a mixed-methods strategy, incorporating both primary and secondary sources of data to ensure a thorough exploration of the subject. The primary data were collected through a questionnaire-based survey targeting farmers across selected local areas that aimed at capturing their experiences, challenges, and practices concerning feed production. The remainder of the data was collected through individual interviews with a variety of stakeholders, such as producers, consumers, government officials, and industry representatives, to seek qualitative insights and contextual nuances.

This study's main objectives are to examine the challenges faced by poultry and dairy farmers, assess the impacts of these constraints, and evaluate government interventions aimed at supporting livestock farmers and improving the overall farming system. Ultimately, the research aims to enhance the resilience of India's livestock industry by providing farmers with insights and tools to navigate uncertainties effectively. This initiative contributes significantly to the realms of food security, economic stability, and environmental preservation within an ever-evolving landscape.

The following research questions will be addressed in the following study:

● What are the major challenges and uncertainties faced by Indian poultry and cattle farmers, particularly in relation to feeding, breeding, healthcare, and veterinary services?

● How effective are current government policies in supporting sustainable feed production and livestock services for poultry and dairy farmers?

● What strategies are being adopted, or can be adopted, to educate farmers and promote the implementation of new technologies in poultry and dairy farming?

● How can government interventions be evaluated in terms of their role in improving productivity, ensuring sustainability, and alleviating rural poverty?

3.2 Research Design

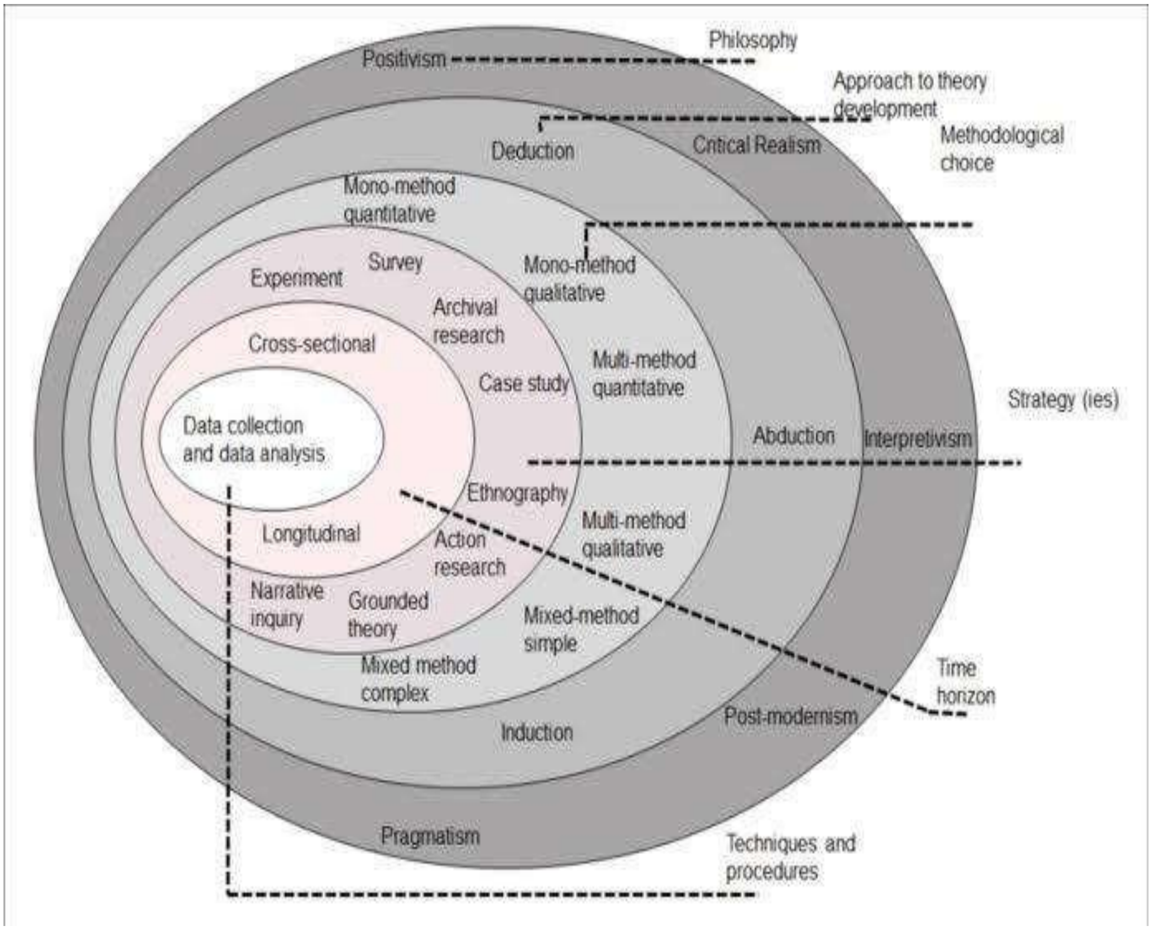

Figure 3.1 Research Onion (Seuring et al., 2021)

The structure of a research study is pivotal in ensuring the successful and streamlined execution of research involving thorough contemplation of diverse elements, such as data collection techniques, researcher proficiency and availability, data arrangement, temporal constraints, and financial parameters (Kumar, 2018).

The experimental research design employs a systematic approach with the aim of deriving specific conclusions from predetermined hypotheses that are established through an extensive literature review (Bell, 2009). Conversely, case studies revolve around established facts and tend to steer clear of employing experimental design methodologies (Rashid et al., 2019). In comparison, field research is often prioritized over theoretical research, finding broad applications across various domains such as science, social sciences, and medicine. In situations where information is scarce, the exploratory research design is employed to gather insights without providing conclusive solutions. This approach is especially useful for addressing novel issues with limited prior information available (Grønmo, 2019). It proves effective in obtaining broader viewpoints (Thorogood and Green, 2018) and uncovering underlying concerns within the domains of social and managerial research. Explanatory research design, conversely, seeks to elucidate and provide rationales for descriptive information, either corroborating or challenging existing explanations. It becomes applicable when correlations are present, yet the impact on a third variable remains uncertain (Rahi, 2017). In contrast, descriptive research design aims to depict phenomena in their inherent context and gain insights into specific occurrences, individuals, or events (Blumberg et al., 2005). Particularly suitable for studies involving mixed or secondary data collection (Colorafi & Evans, 2016), it enables the exploration of multiple variables through diverse methodologies (Snyder, 2019).

Chosen Research Design

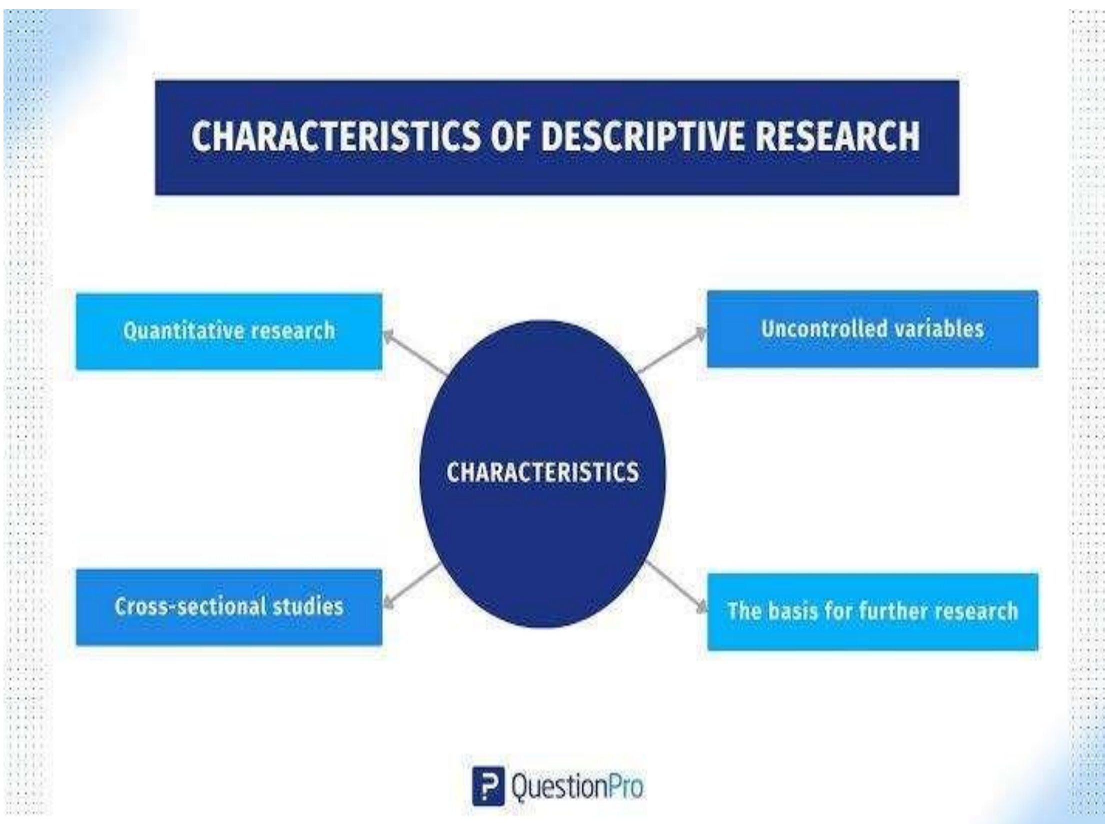

Figure 3.2 Descriptive Research Design (https://www.questionpro.com/blog/descriptive-research/)

The study adopts the descriptive research design since this is able to systematically study and document the present status regarding sustainable feed production for poultry and cattle farmers in India. This design will be appropriate for understanding complex and multi-faceted challenges faced by farmers, policy makers, and industry representatives in the livestock sector. Since descriptive research focuses on "what exists" rather than on establishing causality, it goes in full accordance with the aims put forward by the study, targeting the identification of uncertainties, constraints, and opportunities to be considered within the area of interest.

One of the major reasons for selecting this design is the fact that it allows a comprehensive understanding of the problem at hand. In this case, sustainable feed production in India is affected by several factors, which are socio-economic, technological, and policy-related.

A descriptive research design allows the study to delve into these factors in detail, capturing the nuances of farmers' experiences and broader industry trends. This holistic perspective is essential in the development of meaningful insights and recommendations.

It also involves the mixed-methods approach: integrating qualitative and quantitative data. Above all, descriptive research is appropriately suited for integrating such diverse data. For instance, while qualitative data from stakeholder interviews provide rich, narrative information about the challenges faced by farmers and policymakers, quantitative data from surveys provide patterns and trends that can be measured. This ensures that the analysis is nuanced to answer the research questions comprehensively.

The observational nature of descriptive research also justifies its adoption. The present study does not try to test specific causal hypotheses but rather aims to look out for patterns, relationships, and other key issues in sustainable feed production. This befits a descriptive approach, whose ultimate goal is to methodically record and interpret extant conditions. In addition, this type of research effectively explores context-specific issues which are highly relevant to regional and cultural diversities regarding India's agriculture and livestock sectors.

Finally, a descriptive design enhances the practical applicability of the study's findings. Thorough documentation of prevailing practices, challenges, and opportunities in the research study provides actionable insight for policy, practice, and stakeholders in the livestock industry. This approach ensures that the recommendations from the study are informed by real-world evidence to feed into strategies aimed at improving sustainable feed production in India. Thus, the present study is underpinned by a descriptive research design that provides the appropriate details, integration, and sensitivity to context for comprehensively understanding sustainable feed production in India. Its best appropriateness for the set objectives of the present study, emphasis on mixed-methods integration, and actionability of insights make it the fitting choice for studying the mentioned problem in its complexity.

3.3 Population and Sample

The population of the study includes Indian poultry and cattle farmers, as well as key stakeholders such as government officials, industry representatives, and consumers of the livestock sector. In order to identify respondents, the stratified sampling method is utilized. This method will be followed to ensure the sample represents diversified demographic and regional characteristics of the population, such as farm size, geographic location, and type of livestock reared. Stratified sampling is suitable in this study since it captures the variation across different subgroups. This will help to have a comprehensive understanding of the challenges and opportunities in sustainable feed production.

The stratification criteria included the geographical region, like North, South, East, and West India; the type of farming, which included poultry or cattle farming; and the size of the farm, which, in turn, was categorized into small-scale, medium-scale, and large-scale. To minimize bias and ensure that the findings are reliable, a random selection of respondents was done within each stratum. Selection was based on factors such as feed resource availability, dependency on government policies, and the level of market access, as these relate directly to the objectives of the study.

The sample size was worked out using a confidence level of 95% with a margin of error of 5% to give the results that can represent the whole population. However, in the selection, respondents were chosen based on logistical considerations, such as the accessibility of farmers belonging to far-flung areas and their willingness to divulge information in the questionnaires.

This balanced methodology ensured that robust and representative data were collected while practically feasible to implement. .

3.3.1 Participant Selection

Because of real-world limitations like restricted time and available resources, researchers commonly choose a sample rather than studying the entire population (Taherdoost, 2016). By utilizing a Stratified sampling method, researchers can choose a representative subset that closely aligns with the study's scope and subject. Sampling includes several steps such as identifying the target population, establishing a sampling frame, selecting an appropriate sampling method, deciding on the sample size, gathering the required data, and evaluating how many participants responded to the study. The process is generally categorized into two major techniques: probability sampling and non-probability sampling, each with its own subtypes.

The probability sampling technique ensures equal opportunity for every element in the population to be chosen for the desired sample. There are two common methods to apply this technique. One approach involves the researcher randomly selecting individuals they are familiar with and who meet specific criteria within a defined sampling frame. Alternatively, researchers can outline a relevant population or sampling framework for the study and then use a computer program to generate random numbers, facilitating the selection of a sample from the established frame (Banna, 2018).

This method ensures error-free outcomes and is particularly well-suited for quantitative research methodologies and a positivist research philosophy (Sharma, 2017). Different techniques such as random selection, systematic methods, stratified approaches, and cluster-based procedures can be used to create probability-based samples. Despite potentially consuming substantial time and resources, this approach yields a more accurate representation of the overall population.

Simple Random Sampling

According to Ghauri et al. (2020), simple random sampling guarantees that every individual in the target population has an identical chance of being included in the sample.

Systematic Sampling

The systematic sampling technique involves the systematic selection of every nth element after a random starting point. In this method, individuals are chosen randomly from the population, but their selection follows a numerical pattern. For example, every 7th customer from a list could be selected for a survey. .

Stratified Sampling

Stratified sampling involves dividing the entire population into separate categories or strata, and then drawing a random sample from each of these groups. These strata can be delineated based on various attributes such as company size, occupation, revenue, gender, and more (Sharma, 2017). This sampling approach is particularly valuable when the targeted population showcases a wide spectrum of diversity. The fundamental objective of stratified sampling is to ensure that each stratum of the population is adequately represented within the sample. .

Cluster Sampling

Cluster sampling involves dividing the entire population into separate groups or clusters. A random set of these clusters is then chosen, and the samples taken from them are combined to form a final, comprehensive sample that effectively represents the selected clusters (Wilson, 2014). The application of the cluster sampling approach can greatly enhance the convenience and efficiency of the sampling procedure, especially in cases involving individualized interviews (Kumar, 2018).

Non Probability Sampling

The utilization of non-probability sampling methods is predominantly linked with case study investigations and qualitative research endeavours. In contrast to the domain of quantitative research, case studies are centred around the exploration of real-life phenomena and encompass modest sample sizes (Hancock et al, 2021). This mode of approach empowers researchers to engage in direct interactions and collaborations with respondents, facilitating the collection of their viewpoints and insights (Etikan & Bala, 2017). The classification of non-probability sampling techniques encompasses the following categories:

Convenience or accidental sampling

Convenience sampling involves the selection of samples based on their availability and willingness to participate in the study. It entails choosing participants from a specific geographic area or during a particular time period for the sake of convenience. (Saunders et al., 2015). Despite its limitations, convenience sampling can be valuable in addressing certain research challenges, such as the simplicity of involving family members and peers as participants, as opposed to the complexity of recruiting unfamiliar individuals to achieve the study's objectives.

Purposive or judgmental sampling

Purposive or judgmental sampling is a sampling strategy characterized by the researcher's deliberate selection of specific samples. This choice is based on their judgment and aimed at acquiring relevant information that might remain inaccessible through other approaches (Maxwell, 2012).

Quota sampling

Quota sampling involves selecting individuals according to specific, pre-set traits to ensure the sample accurately reflects the proportional representation of these characteristics within the larger population (Panduranga & Kalapala, 2023). These chosen subgroups are picked to emphasize specific diversities existing within the population (Yang & Banamah, 2014).

Snowball sampling

The snowball sampling technique is a non-random method of sampling that depends on utilizing existing cases to refer and enrol other participants into the study, consequently enlarging the sample size. (Taherdoost, 2016).

Chosen Sampling Method

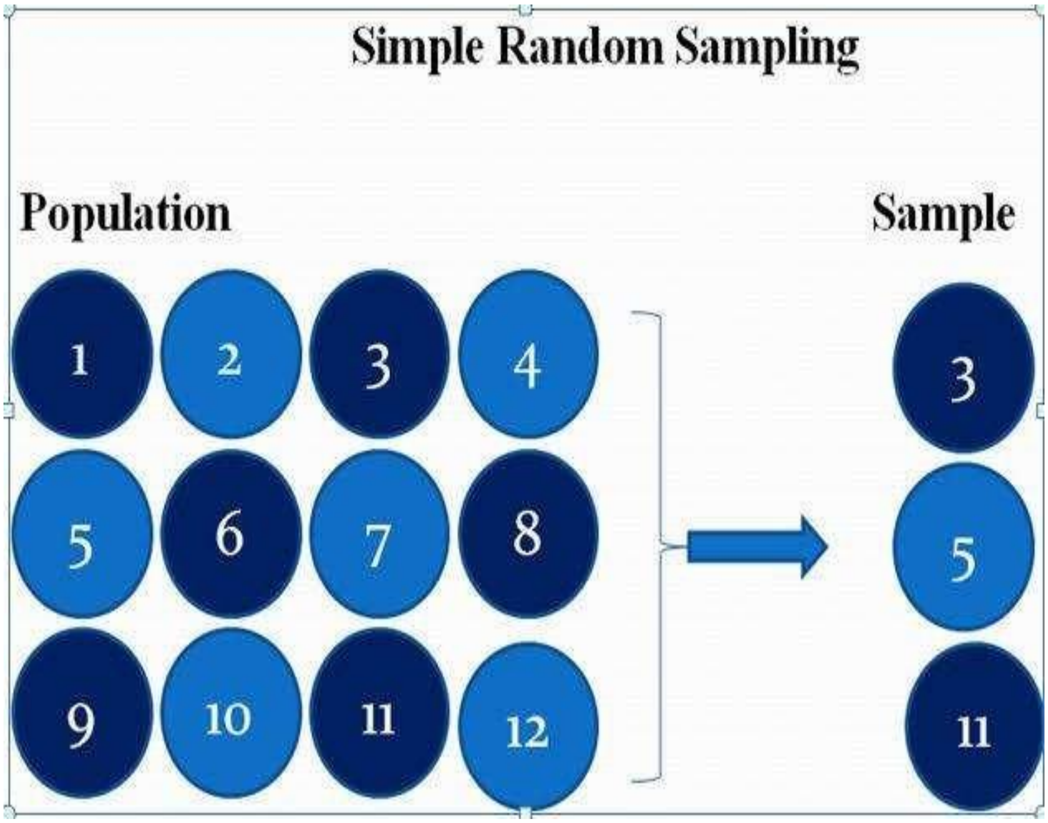

Figure 3.3 :Simple Random Sampling (https://www.statisticalaid.com/simple-random-sampling-definitionapplication-advantages-and-disadvantages/)

To ensure fair and unbiased representation of poultry and dairy farmers from different parts of India, this study adopted the simple random sampling method. This approach was selected to give every farmer an equal chance of inclusion, thereby strengthening the reliability and broader applicability of the study's results.

A total of 400 farmers were surveyed, comprising 143 poultry farmers, 169 dairy farmers, and 88 farmers engaged in both poultry and dairy farming. Data collection was conducted over a two-year period (2022–2023), allowing for a comprehensive assessment of evolving challenges, government interventions, and technological adoption trends in the livestock sector. The sampling locations were strategically chosen to cover a mix of rural and semi-urban areas, ensuring diverse perspectives from farmers with varying levels of access to resources, government programs, and veterinary services.

3.4 Data Collection and Instrumentation

3.4.1 Data Collection Procedures

The process of gathering data assumes a central role in the research framework and methodology, serving as a crucial element in attaining the study's objectives and accumulating substantial empirical evidence. (Paradis et al., 2016). Within this context, there exist three distinct classifications of data collection methods, with the choice of method contingent upon the specific needs and practical feasibility of the study. Furthermore, the selected data collection methodology significantly shapes other components of the research approach. (Miller et al., 2012).

There are three principal data collection techniques: Primary, Secondary, and Mixed data collection, with the Mixed approach combining both primary and secondary data gathering methods. Primary data collection involves the direct acquisition of firsthand information through experiments, observations, or surveys, facilitating direct engagement with the target population (Palinkas et al., 2015). In experimental research, primary data is accumulated during the conduct of experiments. For descriptive research and surveys, including sample surveys or census surveys, primary data is acquired either via observation or by directly interacting with respondents in various ways.

Types of Primary Data Collection:

i) Observation Method

Observation qualifies as a scientific method and data-gathering technique when it is guided by a clear research objective, carried out in an organized and documented manner, and evaluated for both reliability and accuracy. Within the observational method, researchers directly gather and document information without soliciting input from respondents. This approach is particularly useful for studies involving subjects who are incapable of providing verbal reports of their emotions for various reasons. Observational data collection does not necessitate direct personal interaction. A classic illustration of observational data collection involves quantifying the number of vehicles passing through an intersection each hour (Kumar, 2018).

Types of Observation Methods:

- **Structured Observation:** This procedure involves precisely outlining the entities to be observed, devising a methodology for recording the collected data, selecting pertinent observation parameters, and establishing standardized conditions for conducting the observations.
- **Unstructured Observation:** This is carried out without predefining any organized attributes beforehand.
- **Controlled Observation:** It encompasses observation in accordance with predetermined strategies, including experimental methodologies.
- **Uncontrolled Observation:** In this method, the act of observation occurs within authentic or natural settings.
- **Participant Observation:** This technique involves the observer becoming an active participant within a group, thus sharing their experiences.
- **Non-participant Observation:** This approach involves the observer being an uninvolved participant in the process.
- **Disguised Observation:** This pertains to the procedure where observations are conducted discreetly, without individuals being aware that they are under observation.

ii) Interview Method

To effectively carry out the interview method, it's important to thoughtfully choose, train, and keep interviewers updated. They should possess credibility, sincerity, diligence, impartiality, and practical expertise. Indeed, interviewing is a skill that adheres to distinct ethical principles. It entails the exchange of oral-verbal cues and responses through spoken interactions (Kumar, 2022): i) Personal Interview, ii) Telephone Interview.

Interview

This interaction commonly transpires between two individuals: the interviewer and the interviewee or respondent. This method is often favoured when direct communication with the respondents is viable. For instance, a researcher might opt for this approach to gauge individuals' contentment with the service they received from sales staff in the hospitality industry (Mazhar et al., 2021).

- **Personal Interview Method:** This approach includes an individual in the role of the interviewer, asking questions primarily through face-to-face interactions with other individuals. Occasionally, the interviewee might also initiate certain questions and receive responses from the interviewer. However, typically, it is the interviewer who initiates the interview and gathers information. This method is well-suited for in-depth investigations.
- **Structured Interview:** The data collected using this method is usually structured systematically. Such interviews utilize a pre-defined set of questions and employ highly standardized methods for recording. In this approach, the interviewer follows a rigorous procedure.
- **Unstructured Interview:** This method doesn't adhere to a pattern of pre-established questions and standardized approaches for recording data.
- **Focused Interview:** This approach is designed to underscore and prioritize the particular abilities acquired by the respondent and their consequent impacts. Within this method, the interviewer has the flexibility to determine the manner and order of questioning. This flexibility extends to exploring reasons and motivations as well. In a focused interview, the interviewer's primary task involves directing the respondent's discussion toward topics they are knowledgeable about. These interviews are commonly utilized when formulating hypotheses and constitute a significant form of unstructured interviews.
- **Telephone Interview Method:** Through this technique, data is acquired by reaching out to respondents via telephone communication. While not widely adopted, this method carries significance, particularly within the context of industrial surveys.

Collection of Data through Questionnaires

A questionnaire contains a series of questions arranged in a specific order on a form or set of forms. These questionnaires are dispatched to respondents who are expected to read and comprehend the questions, and then provide their responses within the allocated spaces on the questionnaire itself. Participants are responsible for independently providing their answers to the questions (Das and Das, 2011).

Questionnaire: A questionnaire involves a set of predetermined questions provided to multiple respondents. This tool proves useful for collecting information from a wide range of people. Questionnaires are particularly suitable for accessing data from individuals scattered across a broad area and who may not be readily available for in-person interactions. It's essential for a questionnaire to include a concise explanation of the research's objectives. Just like all data collection methods, questionnaires must adhere to ethical and moral standards. An illustrative example of a questionnaire application is India's national population census, which occurs every ten years (Mazhar et al., 2021).

In contrast, **secondary data collection** involves analyzing existing information from sources like magazines, newspapers, and journals. This method is particularly valuable for researchers who have constraints in terms of resources or time. The foundational principles guiding the secondary data collection approach closely mirror those of primary data collection. Researchers have two avenues for utilizing this technique: conducting a qualitative exploration of existing literature and information or harnessing quantitative data from earlier studies to fulfill their research objectives. Adherence to ethical guidelines and copyright regulations is paramount when using secondary data (Johnston, 2017), and accurate citation of data sources is imperative (Padgett, 2016). Prior to incorporating secondary data, researchers should evaluate key attributes like its reliability, relevance, and appropriateness for their research purposes.

To improve research accuracy, scholars frequently adopt a mixed-method data collection strategy that blends primary and secondary sources. This technique, known as triangulation, helps overcome the weaknesses of relying on a single method and significantly strengthens the study’s credibility (Terrell, 2012). Combining information from diverse origins allows for more thorough insights and a richer perspective on the research topic, building on prior academic contributions.

For instance, secondary data is typically used to obtain broad or historical context, while primary data may be added to assess current trends or make comparisons. Drawing on multiple sources not only improves the dependability of the results but also reinforces the overall robustness of the study (Terrell, 2012).

Chosen Data Collection Method

The study employed a mixed-method approach for data collection, incorporating both primary and secondary sources. To gather primary data, responses from 400 farmers in each selected local region were obtained using a structured questionnaire. These responses were later converted into numerical data to help analyze the issue in depth and to precisely assess the impact on poverty reduction.

However, for secondary data collection, data from the published literature studies of commissions and committees formed on the subject of dairy farming, in addition to NDDB and IDA publications was collected during the study. Individual interviews were used instead of secrecy surrounding methods to elicit necessary details about poultry and dairy farming operations from producers, consumers, Government Department officials, and industry people.

3.4.2 Instrumentation

For the current study, a questionnaire-based survey was used to address the research objectives and questions.

Elements that are inherently subjective can only be effectively gathered through direct questioning of respondents. Furthermore, surveys offer a means to gain insights into behavioural patterns. While the observation of behaviour is theoretically possible, it often becomes impractical or expensive, particularly when addressing questions about past behaviours.

Social surveys typically target household populations, though they can also focus on specific subgroups. The strength of survey research lies in its capacity to elicit information on both subjective and objective attributes of a population. However, interview surveys come with notable methodological challenges, primarily related to ensuring a representative sample and the credibility of respondents' answers.

To secure a representative sample, the common practice involves drawing a random sample from the population and employing scientifically validated sampling methodologies. However, the issue of survey nonresponse is significant and growing, particularly in Western countries, potentially undermining the sample's representativeness. Furthermore, the characteristics of both the respondents and the questions posed can influence the nature of the responses obtained. Ensuring the accuracy of the data collected requires rigorous design, evaluation, and testing of the interview questions (Ruggiano and Perry, 2019).

3.5 Questionnaire Development Procedure

The questionnaire is designed to gather insights from Indian poultry and cattle farmers regarding the challenges they face and the impact of government policies on their operations. It consists of six sections: Demographic Details, Government Policies, Poverty Alleviation, Challenges in Farming, Training and Education, and Technology Adoption. Farmers' experiences with feed availability, breeding services, veterinary care, and financial assistance are assessed using a Likert scale. The study also explores how policies support poverty alleviation and modern farming practices. By analyzing farmers' responses, the research aims to identify key obstacles and opportunities in sustainable livestock farming, providing recommendations for policymakers, industry stakeholders, and researchers to improve farming efficiency and economic outcomes.

3.6 Data Analysis Tools and Limitations

3.6.1 Data Analysis Tools

A balanced and thorough assessment of the research questions and goals was carried out using a mixed-methods approach. This strategy combined quantitative and qualitative techniques to examine data gathered through surveys and interviews conducted with poultry and dairy farmers in both rural and semi-urban areas.

The following tools and techniques were used:

1. **Descriptive Statistics**

   Descriptive statistics, including measures of central tendency (mean, median) and variability (standard deviation, range), were used to summarize farmers' demographic profiles, farming practices, and access to resources. These provided a foundational understanding of the dataset and informed the next level of analysis.

2. **Inferential Statistics**

    - **T-tests and ANOVA (Analysis of Variance)** were employed to determine whether there were statistically significant differences between different farmer groups (e.g., trained vs. untrained, regions, or size of operations) in terms of productivity, income, or feed usage.

    - **Multiple Regression Analysis** was used to test hypotheses related to the impact of variables such as government support, feed availability, and veterinary access on farm sustainability and profitability.

    - **Chi-Square Tests** were applied to examine associations between categorical variables, such as participation in training programs and adoption of new technologies.

3. **Qualitative Content Analysis**

    For qualitative data gathered through interviews, **thematic content analysis** was performed. Major themes were coded and categorized to understand farmer perceptions of policy effectiveness, challenges in feed access, and attitudes toward technological adoption.

4. **Software Tools**

    - **SPSS** (Statistical Package for the Social Sciences) was used for quantitative analysis due to its reliability in performing statistical tests and managing large datasets.

    - **NVivo** was used for qualitative data coding and thematic analysis, facilitating systematic interpretation of interview transcripts.

3.6.2 Structure of Data Analysis

The data analysis is structured **in alignment with the research objectives**, not merely by analytical method or data type. Each objective is addressed using appropriate statistical or thematic tools:

- **Objective 1**: Challenges and uncertainties – analyzed using descriptive statistics and thematic coding.
- **Objective 2**: Impact of government interventions – analyzed using inferential statistics (regression, t-tests).
- **Objective 3**: Role of training and technology adoption – examined using Chi-Square and ANOVA.
- **Objective 4**: Evaluation of policy effectiveness – interpreted through regression models and stakeholder insights from content analysis.

This objective-driven structure ensures a logical progression and coherence in presenting findings. Tables and figures are presented only where they support the narrative and analysis, avoiding isolated or unconnected statistical outputs.

3.6.3 Limitations

The choice of data analysis technique is influenced by the selected data collection method and the specific tools employed. For instance, in the case of a qualitative approach involving primary data collection through interviews, thematic analysis is employed to extract major themes from the gathered responses. Conversely, in a quantitative research context, whether using secondary or primary data, statistical data analysis tools are applied to process numerical data. The combination of research approach, data collection method, and tools shapes the specific data analysis technique employed (Panneerselvam and Sivasankaran, 2014).

The analysis tools used in this study to analyze data will involve descriptive statistics, which summarize and interpret data obtained from surveys; inferential statistics comprising t-tests and ANOVA, helpful to examine differences and relationships between variables; and qualitative content analysis to assess themes and insights from stakeholder interviews comprehensively to achieve the research objectives.

In the current study, the data analysis revealed potential issues for poultry and dairy farmers with the help of response sheets. Various regional enterprises of poultry and dairy development and poverty were also determined by mathematical calculations. And the validity of various government policies was also analyzed.

3.6.4 Research Design Limitations

The study aims to explore sustainable animal feed production to enhance profitability and environmental sustainability through farmer-centred practices. However, the research design does come with limitations. One significant limitation is the possibility of sampling bias. The study's focus on participants from specific geographic areas or subsets of farmers could raise questions about the applicability of its conclusions. Additionally, the reliability of the study's findings depends on the data collection methods used, as the lack of standardization in these methods could introduce potential inaccuracies in the dataset.

One more constraint encountered during the study was the shortage of time and resources. This led to a smaller sample size, which may have impacted the strength and reliability of the statistical findings. Including a larger number of participants would have offered more concrete and detailed insights, allowing for a deeper exploration of the varying conditions and issues experienced by farmers in different areas.

Qualitative data collection also has a limited scope in the study. The richness in the insights provided by the qualitative interviews might be inhibited by the limited number and scope, thus not fully capturing the full complexity and diversity of stakeholder perspectives. This may leave out some critical nuances specific to some regions or farming systems.

Last but not least, the research design focuses mainly on sustainable feed production, hence overlooking other important aspects that are critical to livestock farming. Major issues such as market dynamics, infrastructure challenges, and the adoption of new technologies, which equally remain crucial to the success of livestock farming, are not looked into in detail, and this limits the wider applicability of the findings.

3.7 Ethical Considerations

This research strictly followed ethical standards to protect the integrity of the study, maintain participant confidentiality, and ensure that involvement was voluntary. Before beginning data collection, all 400 farmers and interview participants were clearly informed about the research objectives, scope, and how the information would be used. Their consent was obtained with full understanding. Participation was completely optional, and individuals were free to opt out at any point without facing any negative consequences. Personal data and responses were anonymized to protect participants' identities and privacy. Interviews were conducted with transparency and without coercion, respecting the cultural and social sensitivities of rural and semi-urban communities. Additionally, ethical clearance was secured where required, and data collected from secondary sources, including NDDB and IDA publications, was properly cited and used responsibly. All research practices followed ethical standards in accordance with institutional and national research guidelines.

3.8 Conclusion

The current methodology emphasises the vital necessity to direct attention towards the collection of challenges prevalent in the agricultural sector to address uncertainties in sustainable feed production for Indian poultry and cattle farmers. Through dedicated research efforts aimed at creating climate-resilient feed, formulating nutrient-efficient compositions, and optimizing farming practices, the agricultural sector can enhance its ability to effectively navigate changing environmental dynamics. This scientific foundation not only facilitates efficient resource utilization but also reduces the ecological impact associated with feed production.

Altogether, the methodology highlights the significance of involving stakeholders at various levels, which encompass farmers, industry experts, governmental bodies, and environmental organizations to cultivate a supportive ecosystem encouraging an exchange of knowledge, capacity enhancement, and promotion of favourable policies. Through this integrated approach, the agricultural sector can make substantial advancements in ensuring food security, preserving environmental balance and promoting sustainable economic growth.

CHAPTER IV

RESULTS

4.1 Introduction

The chapter discusses the results of the study based on primary and secondary data collected for achieving the research objectives of sustainable feed production challenges and opportunities for Indian poultry and cattle farmers. It clearly arranges the findings for a systematic interpretation of the information, thus achieving the purpose of the study by identifying critical barriers and potential strategies for sustainable practice. The primary data, collected through a survey with farmers and interviews with stakeholders, have thus far been analyzed to throw light on key trends, patterns, and insights into the reality of feed production and its impact on farmer livelihoods.

4.2 Organization of Data Analysis

4.2.1 Descriptive Results

Demographic Information

Age				
Valid	**Frequency**	**Percent**	**Valid Percent**	**Cumulative Percent**
18-30 years	**106**	**26.5**	**26.5**	**26.5**
31-40 years	**194**	**48.5**	**48.5**	**75.0**
51-60 years	**100**	**25.0**	**25.0**	**100.0**
Total	**400**	**100.0**	**100.0**	

Table 4.1: Age table

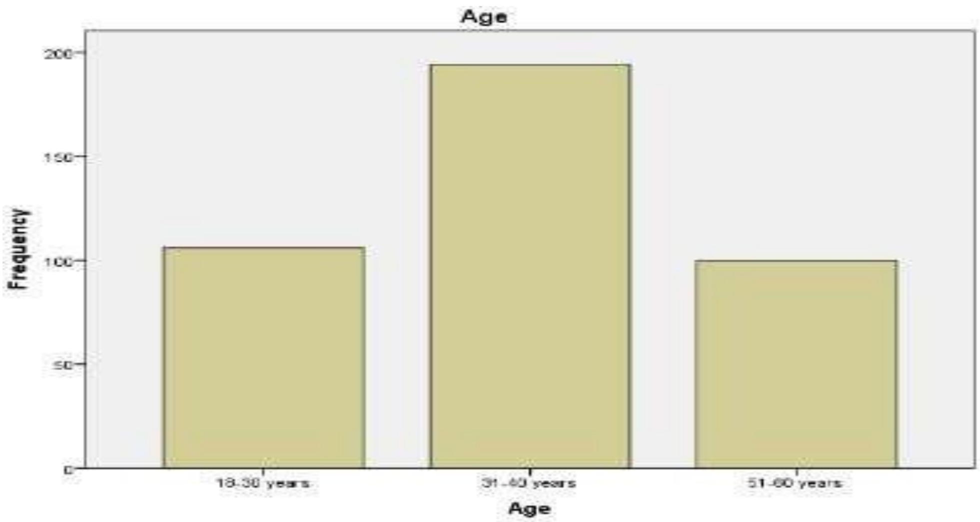

Figure 4.1: Age

Age is an important demographic factor determining a farmer's predisposition towards adopting new practices or technologies. In this regard, there was a reasonably wide age spread among the participants; however, 48.5% of the participants were compulsorily fixed between 31-40 years of age. This argues for and confirms that most respondents in the sample have dominant productive years and are likely more receptive to knowledge on adopting new technologies or sustainable farming practices. Also, 25 percent of the overall farmers were in the age bracket of 51-60 years, who can offer experience in farming but may be more skeptical of changing practices. The other significant percentage was that belonging to the 18-30 years age group, 26.5 percent, which would be relatively open to adopting the new methods and technologies, though a few constraints may arise due to a want of experience. Understanding the age distribution helps in the explanation of how different generations approach sustainable feed production and their reception to government programs and technological innovation.

Gender					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Female	185	46.3	46.3	46.3
	Male	211	52.8	52.8	99.0
	None-Binary	4	1.0	1.0	100.0
	Total	400	100.0	100.0	

Table 4.2: Gender Table

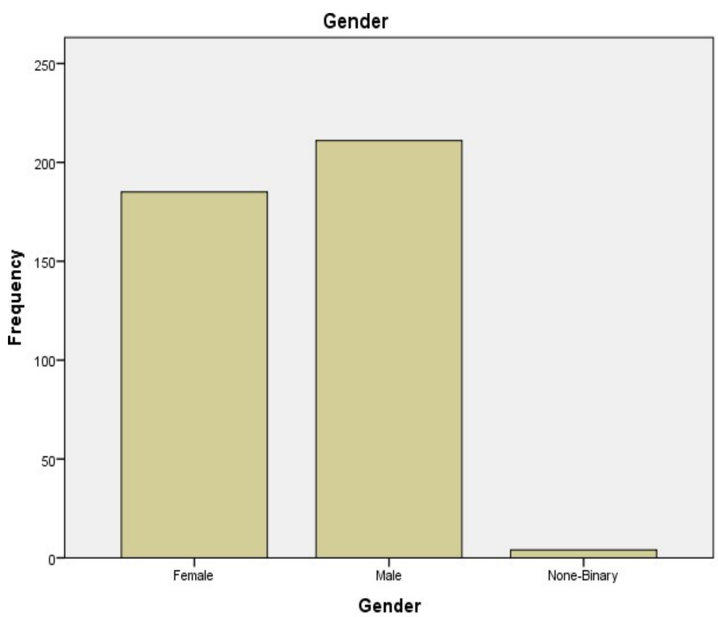

Figure 4.2: Gender

It is expected that gender will play an important role in shaping the nature of agricultural production in most countries like India, where cultural and societal norms have a great say in the gender roles men and women have to play. The sample contains a slightly larger fraction of males, with 52.8%, while females constitute 46.3% of the population, the rest being a negligible fraction turning out to be non-binary. This relatively even gender distribution reflects the involvement of both males and females in livestock keeping, with traditional male dominance in certain segments of farming. More specifically, active women's involvement in poultry and dairy farming is particularly important since these sectors often include home-based and small-scale production systems in which women usually play a very critical role in managing daily operations. It will be important to understand gender dynamics in order to design policies and programs that meet the particular problems of both male and female farmers.

Education					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No Education	60	15.0	15.0	15.0
	Primary Education	120	30.0	30.0	45.0
	Secondary Education	220	55.0	55.0	100.0
	Total	400	100.0	100.0	

Table 4.3: Education Table.

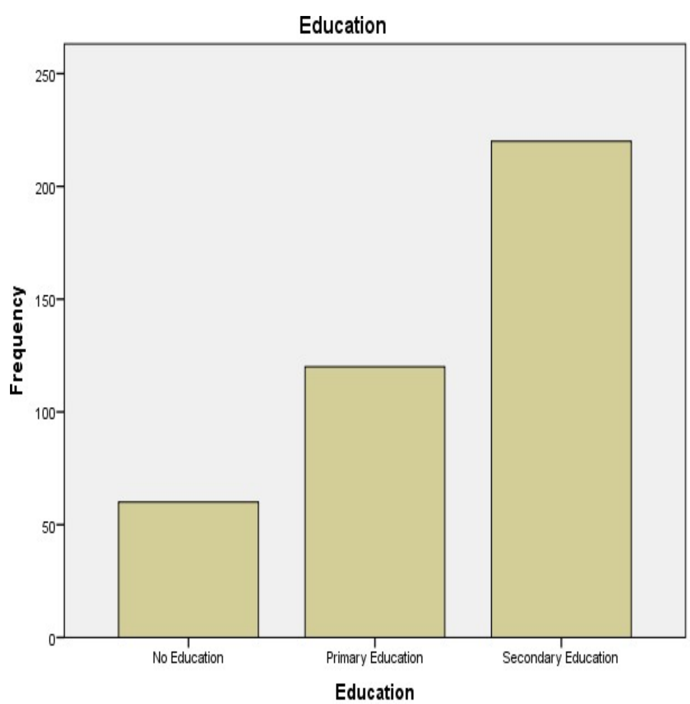

Figure 4.3: Education

The level of education determines whether any particular farmer can apply new technology, understand government policies, or practice sustainable farming. From the educational background, the majority of respondents represented 55% who had completed secondary school, hence meaning that the farmers were relatively well-educated and could understand and implement modern techniques in farming. A third of the respondents reported primary education only, probably limiting their potential to access advanced knowledge and skills relevant for sustainable feed production. Further, a total of 15% of the respondents had no formal education and thus, presumably, would present the group that could have significant difficulties in mastering and adopting the intricate processes included in sustainable farming. These different levels of education show the need for specific training programs and educational resources to be made available for farmers with diverse educational backgrounds.

Marital Status					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Married	214	53.5	53.5	53.5
	Separated	3	.8	.8	54.3
	Single	183	45.8	45.8	100.0
	Total	400	100.0	100.0	

Table 4.4: Marital Status Table.

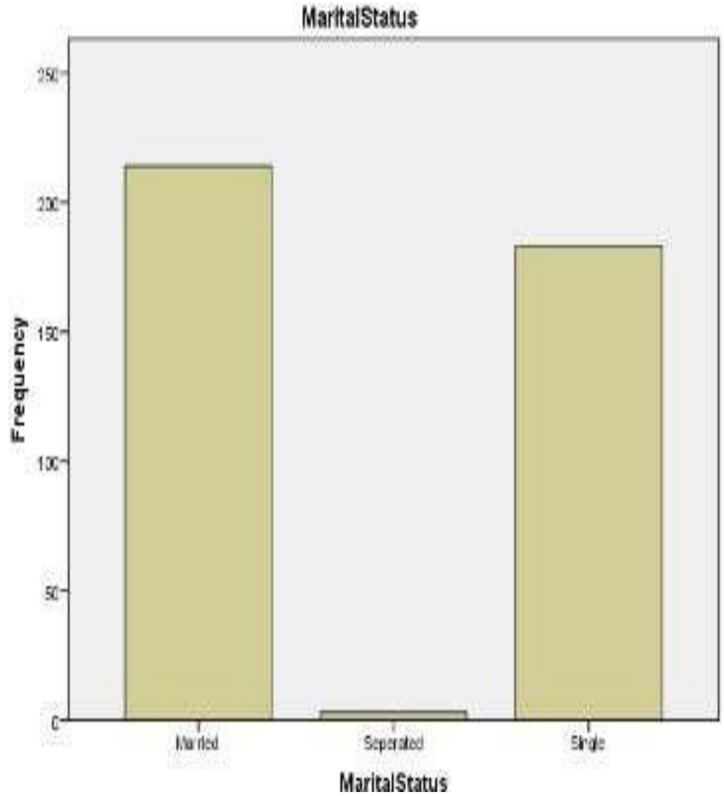

Figure 4.4: Marital Status

Indirectly, marital status may have an impact on the farmer's responsibilities and resources such as family labor availability, household income, and support systems. In the present survey, 53.5% of the respondents were married, 45.8% were single, and a small fraction separated. A married farmer is more likely to have more family members to help him with farm operations, particularly in rural Indian villages where farming is still a family occupation. Other conditions that could favor investment decisions in new technologies and more sustainable farming methods are supportive family structures where more members contribute to labor and make decisions in the family. In solitary or separated situations, farmers would then face particular challenges like a reduced number of laborers and resources, which might be at a disadvantage with respect to adopting new practices.

Income					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	10,00,000 - 14,99,999	50	12.5	12.5	12.5
	15,00,000 - 19,99,999	68	17.0	17.0	29.5
	2,00,000 - 4,99,999	110	27.5	27.5	57.0
	20,00,000 or more	61	15.3	15.3	72.3
	5,00,000 - 9,99,999	59	14.8	14.8	87.0
	Less than 2,00,000	52	13.0	13.0	100.0
	Total	400	100.0	100.0	

Table 4.5: Income group

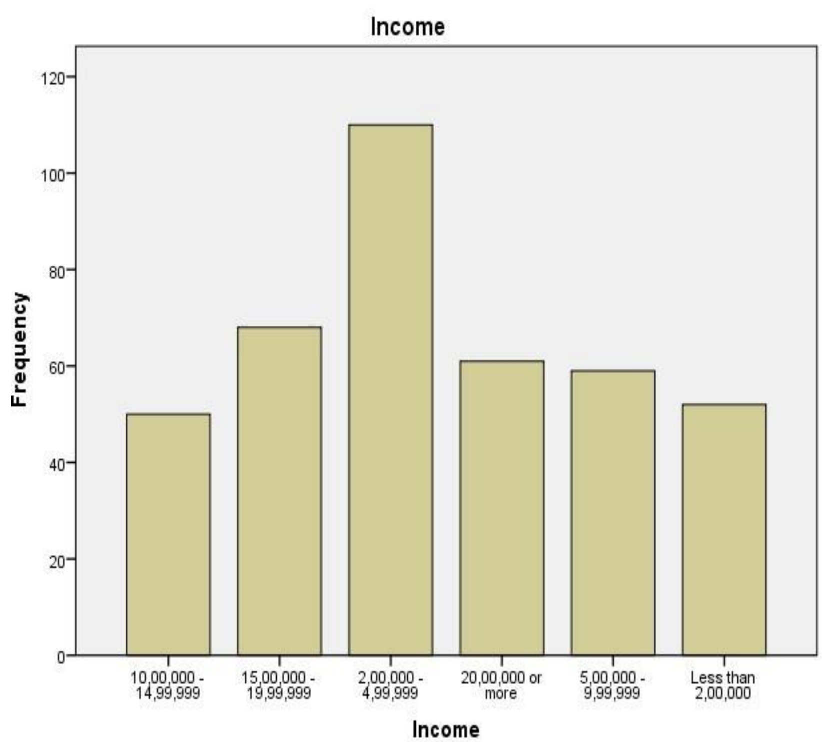

Figure 4.5: Income Level

Income level is a major determinant of the ability to invest in new technologies or improve sustainability on farms. The respondents farmers reported their income level to range between 200,000 and 499,999 INR every year for the highest category, amounting to 27.5% of them. Farmers with such an income level belong to the middle-income group and thus need assistance through different governmental subsidies and financial assistance to enhance their farm operations.

Other brackets included those earning within the range of 1,500,000-1,999,999 INR at 17%, while those at the level of 500,000-999,999 INR contributed 14.8%. Only 13% had an income below 200,000 INR, clearly showing economically vulnerable farmers unable to afford access fuentes and necessary investments for sustainable farming. This is important in understanding income disparities as a way of targeting government programs and financial support where it is needed.

Farmer Type					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Cattle Farmer	169	42.3	42.3	42.3
	Poultry Farmer	143	35.8	35.8	78.0
	Both	88	22.0	22.0	100.0
	Total	400	100.0	100.0	

Table 4.6: farmer type table

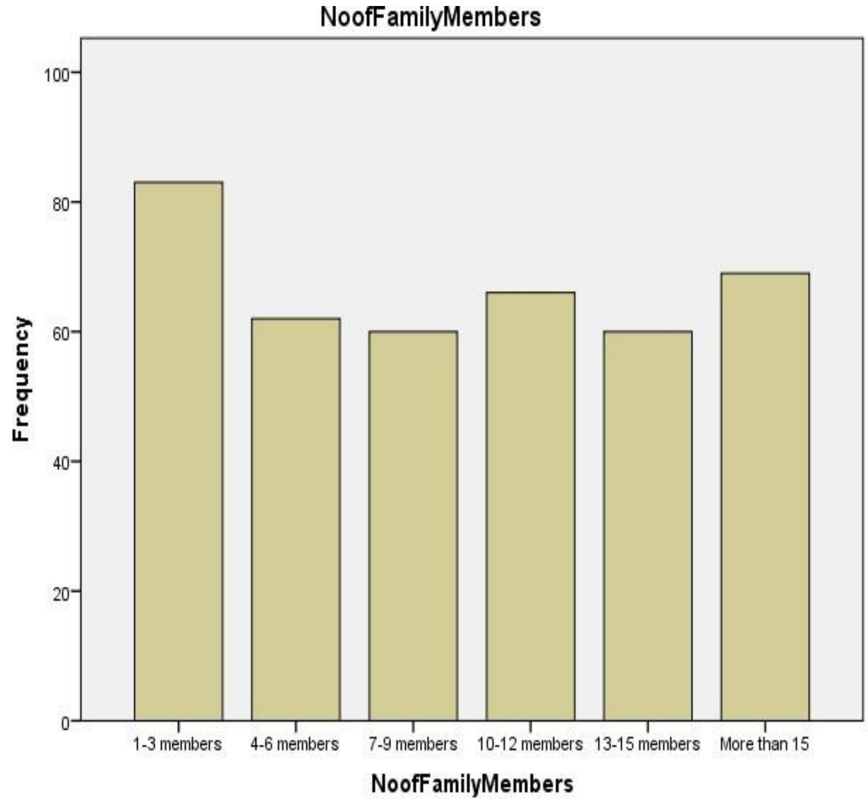

Figure 4.6: Number of Family Members

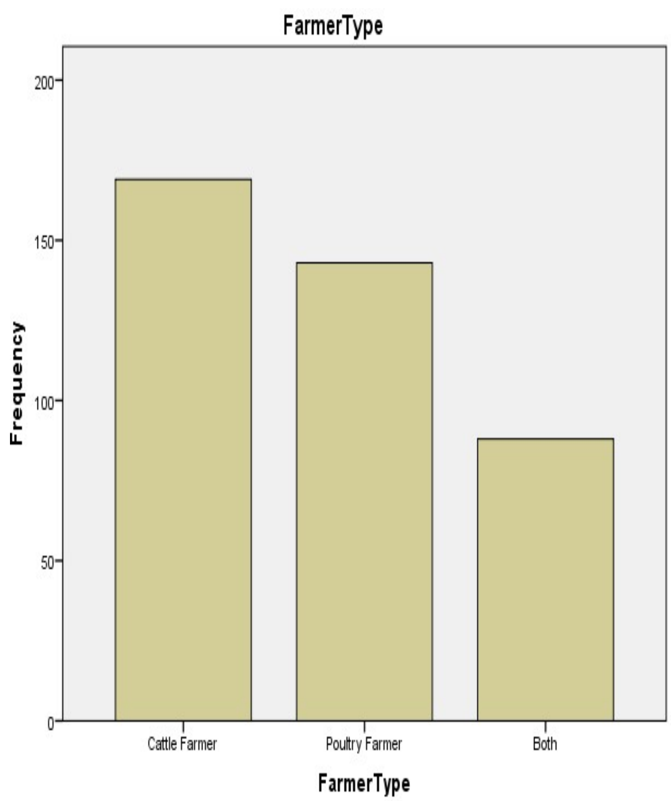

Figure 4.7: Farmer Type

Most of them were cattle farming at 42.3%, followed by poultry farming at 35.8%, while those who involved themselves in both poultry and cattle farming constituted 22%. The above distribution pinpoints the importance of sustainable feed production in both sectors since each sector faces its challenges and opportunities to be tackled in policy development and technological implementation.

4.2.2 Challenges in Sustainable Feed Production

Availability of High-Quality and Affordable Feed

Government regulations on cattle farms are leading to economic strain on Indian poultry and dairy producers, hence improving their overall productivity and profitability.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	38	9.5	9.5	9.5
	Disagree	68	17.0	17.0	26.5
	Neutral	80	20.0	20.0	46.5
	Agree	131	32.8	32.8	79.3
	Strongly Agree	83	20.8	20.8	100.0
	Total	400	100.0	100.0	

Table 4.7: Government regulations on cattle farms are leading to economic strain on Indian poultry and dairy producers, hence improving their overall productivity and profitability.

One of the main issues faced by Indian poultry and dairy farming is the demand for unavailability of quality and reasonably priced feed. In the data, 32.8% agreed that quality feed is not available in enough quantity within their region, while 17.8% strongly agreed. The inaccessibility of good quality feed affects livestock output: low-quality feed means low growth rates, low production of milk and eggs, and vulnerability to diseases. The lack of reasonably priced, nutritionally valuable feed is considered to be a key burden in rural areas since farmers depend on local suppliers who may not have access to better sources of feed.

The shortage of quality feed can also be blamed on the inefficiencies in the supply chain. In most cases, feed suppliers are not found within reach of many regions. The gaps between farms and suppliers are long enough to make it difficult to rely on distant people due to increased transportation costs. In fact, 39% of the respondents in this research agreed that accessibility to reliable feed suppliers and retailers is poor. This usually involves a high transport cost from an urban centre or a far-away supplier, hence setting a higher price that may not be affordable to the small-scale farmer for his chosen sustainable feed option.

Storage and Preservation of Feed

Even when feed is available, storage and preservation remain a big challenge for many farmers. About 36% of the respondents reported that storing and preserving feed on their farms was quite challenging. In most cases, the farmers lack appropriate storage facilities which can shield feed from spoilage and pests and environmental conditions like humidity and heat, which easily degrade the nutritional quality of feed. Poor storage practices result in massive waste, which only increases the cost of feed for already financially strained farmers.

The problem of feed preservation is of primary importance in rural areas where lack of infrastructure predominates. Smallholder farmers mostly remain devoid of the facilities of modern storage, such as silos or airtight containers, to store feed for longer intervals. This limitation ultimately compels farmers to buy feed more frequently, increasing the cost of transportation and hence the burden of raising the overall cost of feed management.

Limited Access to Grazing Land

The next most common problem reported by the farmers is the lack of access to grazing land, particularly for cattle-raising. About 29.8 percent of the respondents strongly agreed that lack of access to grazing land is one of the major problems in their community. Grazing is an important husbandry practice to this day in sustainable livestock operations, especially among small-scale farmers who often have the inability or lack of resources to buy a lot of commercial feed. The open land allows the animals to graze naturally hence reducing many feeding costs, besides contributing to the good health and well-being of the animals.

In many respects, land is becoming scarcer in terms of usable resources because of urbanization and industrial development, and the simple conversion of lands from agricultural uses. This consequently reduces the possibility for farmers of natural grazing; they have to purchase feed at a more expensive price, which may be less sustainable in the longer term. The competition for the grazing fields also results in overgrazing in some areas, reducing the possibility of land regeneration and future use with livestock.

Adoption of New Technologies in Feed Production

The study recommended the adoption of modern technologies of feed production to ensure sustainability within poultry and dairy farming. However, many farmers have cited several barriers in their attempts to adopt such technologies. The study indicated that 41.8% of the respondents agreed or strongly agreed that it is easy and supported when adopting new technologies within farming operations. But this still leaves a substantial percentage of farmers for whom the seeking out or application of new technologies remains problematic, doubtless because of financial, educational, or infrastructural obstacles. Probably one of the key limiting factors to the slow rate of adoption of technologies of sustainable feed is financial.

While some governmental programs offer subsidies or other forms of financial aid, investment in equipment or feed systems that would make sustainable production or storage of feed feasible is beyond the reach of most farmers. Besides, the cost of sophisticated feed production technologies can often be prohibitively expensive for small-scale farmers to shift methods to something that may be cheaper in the short run but less viable longer term. Other major factors that contribute to the abysmal rate of technology adoption inside the country can be attributed to a lack of technical knowledge on the part of farmers. The financial support may be there, but in many instances, proper training or technical assistance is not even available to farmers for their use in utilizing the new technologies efficiently. Results show that in this study, 37.8% agreed that adequate technical assistance in implementing government programs is available, but that a substantial number of farmers might still lack either the requisite skill or confidence to implement modern feed practices.

Breeding and Veterinary Services

Access to high-quality breeding stock

Government policies promote the availability of superior feed and veterinary services to increase income for the farmers.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	40	10.0	10.0	10.0
	Disagree	61	15.3	15.3	25.3
	Neutral	91	22.8	22.8	48.0
	Agree	127	31.8	31.8	79.8
	Strongly Agree	81	20.3	20.3	100.0
	Total	400	100.0	100.0	

Table 4.8: Government policies promote the availability of superior feed and veterinary services to increase income for the farmers.

Farmers consider one of the main challenges to be that high-value breeding stock is lacking. Access to healthy and genetically superior breeding animals, such as bulls for dairy farming or hens for poultry farming, is highly important to raise the productivity of livestock. However, fully 31.8% of all respondents agreed with the statement that high-value breeding stock is hard to come by in their area, while another 13.5% strongly agreed with this statement . Poorer quality breeding stock result in lower milk and egg yields, poor animal health, and reduced genetic diversity of critical importance to eventual sustainable livestock.

Several are the contributing factors to this problem. Firstly, most small-scale farmers are not in a position to afford high-quality breeding animals due to the high cost of such breeds. The access to high-quality breeds is costly and tricky, especially in rural areas; limited breeding studs and services. Besides, the lack of formal breeding programs aimed at ensuring a constant supply of improved breeding materials forces farmers into adopting local breeds, which are always inferior. General lack of proper infrastructure in the rural areas heightens the problem as the farmers do not have access to artificial insemination facilities or even professional advice on how to acquire the most superior sets of breeding animals that suit their farms.

Artificial Insemination and Government-Funded Breeding Programs

Artificial insemination is an important tool in enhancing genetic quality and increasing animal production. However, the study showed that 37.5 % agreed that accessibility to artificial insemination is limited, while 23.8 % strongly agreed. The use of AI in breeding their animals by dairy and poultry farmers is, in turn, dependent on this, since it can be performed in a controlled environment which allows the selection of animals with desirable traits without necessarily having to undergo direct mating. AI can be in support of and mitigate the risk of disease transmission with natural breeding methods.

Besides, an insufficient number of qualified technicians and lack of proper infrastructure in rural areas are the usual reasons for limited access to AI services. AI requires specially designed equipment, as well as skilled professionals to use it; more often than not, none could be found in underdeveloped regions to employ AI successfully. Again, because proper understanding is always lacking among farmers as far as the input of AI and its benefits concerning livestock are concerned, less administration of the technology may be expected.

Similarly, access to the government-funded breeding program is reportedly still limited. About 41.5% of the respondents agreed that access to such programs is not easy, whereas about 22% strongly agreed. In fact, these programs were meant to give farmers access to superior genetics as well as other AI services at subsidized rates. Nonetheless, bureaucratic inefficiencies, unawareness of the initiated programs, or geographical settings do not permit farmers to access such initiatives. Resulting from this, many farmers do not benefit from government resources which may be very important in enhancing their practices of livestock breeding.

Veterinary Care and Access to Veterinary Services

Veterinary services will be very important in maintaining the health and productivity of their livestock, but the study indicated that many different challenges are faced by the farmers in accessing the services. Some of the key barriers reported include the cost of veterinary care. About 37.8% of the respondents agreed that the cost of veterinary health care and medication hinders them from seeking timely healthcare for their animals. This problem is, however, more heightened in small-scale and subsistence farmers due to the meager budget and lack of disposable income that could permit access to routine veterinary checkups and treatments. In addition to the costly nature of the veterinary services, treatment is usually delayed, which increases the possibility of disease outbreak and reduces general productivity on the farm.

Cost of veterinary care and medication as a barrier to seeking timely healthcare for domesticated birds and cattle.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	24	6.0	6.0	6.0
	Disagree	36	9.0	9.0	15.0
	Neutral	74	18.5	18.5	33.5
	Agree	151	37.8	37.8	71.3
	Strongly Agree	115	28.8	28.8	100.0
	Total	400	100.0	100.0	

Table 4.9: Cost of veterinary care and medication as a barrier to seeking timely healthcare for domesticated birds and cattle.

It is bad enough that there will be a limited amount of finances available; what complicates matters even further is the shortage of professional veterinarians. That is to say, about 38.3% of the respondents reported that a shortage of veterinary doctors is a major constraint, while another 30% strongly agreed. In fact, accredited vets are hardly available in most of the rural areas; as such, to receive the services, farmers have to cover long distances either to veterinary clinics or hospitals. This is one of those geographic challenges that further aggravates the problem, especially in emergencies when such attention becomes very vital for survival. For instance, 35.5% of the respondents reported that the big distance to veterinary clinics is one of the main deterring factors impeding them from seeking veterinary services. Circumstances have ways of then forcing many into falling back on unqualified practitioners or even self-medication, notorious possibilities for causing damage to animal health.

A shortage of veterinary doctors is a significant constraint in accessing veterinary care for cattle/birds.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	26	6.5	6.5	6.5
	Disagree	38	9.5	9.5	16.0
	Neutral	63	15.8	15.8	31.8
	Agree	153	38.3	38.3	70.0
	Strongly Agree	120	30.0	30.0	100.0
	Total	400	100.0	100.0	

Table 4.10: A shortage of veterinary doctors is a significant constraint in accessing veterinary care for cattle/birds.

Diagnostic Services and Disease Prevention

Early disease diagnosis eventualizes the reduction of mortalities in livestock and sustains their productivity. However, many farmers have limited access to diagnostic services. In this study, 37.8% of the respondents agreed that access to diagnostic services for cattle and poultry is very limited. Access to diagnostic tools enables early diagnosis of diseases and the adoption of treatment strategies in good time. Farmers usually lack proper diagnostic tools and services; hence, they fail to identify the signs of sickness at early stages. Appropriate intervention is therefore usually done at later stages of the disease, leading to increased mortality.

Access to diagnostic services for cattle and birds is very limited.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	29	7.3	7.3	7.3
	Disagree	43	10.8	10.8	18.0
	Neutral	62	15.5	15.5	33.5
	Agree	151	37.8	37.8	71.3
	Strongly Agree	115	28.8	28.8	100.0
	Total	400	100.0	100.0	

Table 4.11: Access to diagnostic services for cattle and birds is very limited.

Limited vaccine availability and preventive care are the major factors impeding disease prevention. Thirty-seven percent of the respondents believed that a lack of effective vaccine is one of the major causes preventing the potential for disease prevention in domesticated birds-23.5% strongly agreed. Vaccination against some of these prevalent diseases among livestock is important, although many farmers do not have access to vaccines or are unable to afford them on a regular basis. The failure to take such preventive care leaves animals exposed to outbreaks that can spread so fast and wipe out whole flocks or herds.

Government Support and Policies

Financial Support and Subsidies

One of the most significant kinds of government support for farmers is financial. Financially in the form of a subsidy or in the form of direct aid-farmers can invest in new technologies that enhance their operations and cope with the increasing feed costs, veterinary services, and equipment. Results show that 32.5% agree that enough financial support is given to farmers to adopt new technologies, while another 34.5% strongly agree. This positive response may indicate the benefit derived by many farmers through financial assistance programs in order to adopt new practices that improve their productivity.

Adequate financial support is provided to farmers for implementing new technologies

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Agree	130	32.5	32.5	32.5
	Disagree	39	9.8	9.8	42.3
	Neutral	71	17.8	17.8	60.0
	Strongly Agree	138	34.5	34.5	94.5
	Strongly Disagree	22	5.5	5.5	100.0
	Total	400	100.0	100.0	

Table 4.12: Adequate financial support is provided to farmers for implementing new technologies

However, even though a relatively high percentage responded to satisfaction with government financial support, financial constraints still remain for many farmers. Farmers in general, and particularly small-scale and subsistence farmers, are likely to have inadequate access to credit or other financial resources to invest in long-term sustainable solutions. Further, while government subsidies for feed and veterinary services are appreciated by 34% of the respondents, an indication that the programs contribute positively toward feed sustainability, there is still room for expansion of such programs to reach out to more farmers in remote or less-served areas.

Tax Exemptions and Incentives

Besides this direct financial endowment, tax exemptions on farming activities encourage the growth and development of livestock farms. This indicates that 37.8% of the respondents agreed to the issue that tax exemption has contributed significantly to the growth of cattle and poultry farms, while 13% strongly agreed. These incentives minimize the burden and provide enough confidence for investment in modern farming, such as feed production technologies and veterinary services. Lowering farm operations costs through such tax policies allows farmers to invest more in the health and productivity enhancement of the animal.

Tax exemption in farming activities plays a significant role in the growth of cattle/poultry farms in India.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	24	6.0	6.0	6.0
	Disagree	77	19.3	19.3	25.3
	Neutral	96	24.0	24.0	49.3
	Agree	151	37.8	37.8	87.0
	Strongly Agree	52	13.0	13.0	100.0
	Total	400	100.0	100.0	

Table 4.13: Tax exemption in farming activities plays a significant role in the growth of cattle/poultry farms in India.

However, not all farmers are fully informed about their potential tax privileges, or they may be impeded by the bureaucratic process responsible for the exemptions. Increasing awareness of tax policy, coupled with simplification of procedures in claiming benefits, may be necessary to further improve the effectiveness of the tax incentives in encouraging sustainable farming practices.

Veterinary Services and Health Programs

Efforts by the government include improving veterinary services, such as vaccination drives and subsidized veterinary care. Government-sponsored vaccination programs are a key component in sustaining the livestock's health status and preventing the outbreak of diseases. Precisely, 28.8% of the respondents agreed that vaccination drives are important ways to maintain animal health, while 17% strongly agree. Such programs have immense importance in rural areas where access to private veterinary services may be difficult for farmers, and the cost of vaccinations may also be unaffordable.

Government-funded vaccination drives play an important role in maintaining the health of farm animals.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	37	9.3	9.3	9.3
	Disagree	85	21.3	21.3	30.5
	Neutral	95	23.8	23.8	54.3
	Agree	115	28.8	28.8	83.0
	Strongly Agree	68	17.0	17.0	100.0
	Total	400	100.0	100.0	

Table 4.14: Government-funded vaccination drives play an important role in maintaining the health of farm animals.

Nevertheless, the increase in access to veterinary services remains one of the biggest challenges facing most farmers despite such programs. Results have shown that 38.3% of those surveyed reported the shortage of veterinary doctors, and 37.8% agreed to the fact that the cost of veterinary service is among the main reasons for not approaching treatment in due time for their animals. Even though governmental programs bring some relief, the overall availability of veterinary services is incomplete, especially within remote areas. These, along with the expansion of government veterinary programs, improvement in infrastructure, and increase in qualified veterinarians in rural areas, can be considered some of the steps toward addressing these challenges.

Skill Development and Training Programs

Programs related to education and the development of different skills will contribute to farmers adopting new technologies and methods of farming that are in line with sustainability. Skill development programs sponsored by governments have also been widely implemented to help farmers to improve their incomes through better farming techniques. From the study, 37.8% of the respondents agreed to the skill development programs helping increase their income, while 20% strongly agreed. These address training programs in sustainable feed production, animal health management, and modern technologies of farming that help farmers improve the productivity and sustainability of their respective farms.

Government-sponsored skill development programs help in increasing the income of cattle and poultry farmers in India.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	29	7.3	7.3	7.3
	Disagree	60	15.0	15.0	22.3
	Neutral	80	20.0	20.0	42.3
	Agree	151	37.8	37.8	80.0
	Strongly Agree	80	20.0	20.0	100.0
	Total	400	100.0	100.0	

Table 4.15: Government-sponsored skill development programs help in increasing the income of cattle and poultry farmers in India.

Regulatory Policies and Economic Strain

While government policies are generally in support of farmers, several of the regulation measures could throw a cost burden on the sector. For example, 32.8% agreed that government regulations promulgated on cattle farms have led to economic strain. An additional 20.8% strongly agreed. These regulations may pertain to certain restrictions on land use, grazing rights, and environmental compliance that create a cost burden on the already thin-margin farmers. It will be quite a balancing act between necessary regulation and the economic realities of small-scale farmers so that policies will not stifle growth or discourage innovation.

Government regulations on cattle farms are leading to economic strain on Indian poultry and dairy producers, hence improving their overall productivity and profitability**.**

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Disagree	38	9.5	9.5	9.5
	Disagree	68	17.0	17.0	26.5
	Neutral	80	20.0	20.0	46.5
	Agree	131	32.8	32.8	79.3
	Strongly Agree	83	20.8	20.8	100.0
	Total	400	100.0	100.0	

Table 4.16: Government regulations on cattle farms are leading to economic strain on Indian poultry and dairy producers, hence improving their overall productivity and profitability**.**

Reliability Statistics

Reliability of Measurement Instrument

To evaluate the internal consistency of the survey tool, a reliability analysis was performed using Cronbach's Alpha. The questionnaire included 30 items based on the Likert scale and was administered to a sample of 400 respondents. The resulting Cronbach's Alpha value was 0.949, indicating a high level of reliability. In the context of social science research, values above 0.7 are considered acceptable, while those exceeding 0.9 reflect excellent reliability. The high value obtained in this regard shows that the items were consistent in measuring the key constructs around sustainable feed production, government support, and challenges in breeding and veterinary services.

Table 4.17: Reliability Statistics

Cronbach's Alpha	N of Items
.949	30

The item-total statistics indicated that each item made valuable contributions to the total reliability of the scale. Items like "It is difficult to maintain housing for domesticated birds" had a corrected item-total correlation of 0.760, while other items such as "It is hard to find veterinary clinics or hospitals" had lower correlations. While several of the items showed relatively low correlations, the overall high value of Cronbach's Alpha suggests that the survey tool was reliable and did provide consistent results across the sample. Therefore, reliability analysis confirms that the survey has captured perspectives and challenges from the respondents in the study.

Cronbach's Alpha Value

Item-Total Statistics				
	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Tax exemption in farming activities plays a significant role in the growth of cattle/poultry farms in India.	102.20	484.697	.617	.947
Government-funded vaccination drives play an important role	102.25	487.355	.501	.948

in maintaining the health of farm animals.				
Government subsidiaries for Feed and veterinary services help me maintain a sustainable poultry/cattle farm.	102.27	479.127	.656	.946
Government policies promote fair market access and pricing for poultry/dairy products, leading to increased income for the farmers.	102.15	483.470	.560	.947
Government regulations on cattle farms are contraning my farm's productivity.	102.07	475.000	.726	.946
Government-provided microfinance schemes are effective for cattle and poultry farmers in poverty alleviation efforts.	102.14	477.859	.744	.946
Government policies promote inclusive and equal opportunities for marginalized groups within cattle and poultry farmers.	102.01	475.413	.753	.946
Government-provided financial assistance programs contribute to the alleviation of poverty among cattle and poultry farmers.	102.21	481.718	.608	.947
The government is effectively addressing	102.09	477.580	.745	.946

the infrastructure-related issues (access to water, roads, and electricity) that affect the livelihood of poor farmers.				
Government-sponsored skill development programs help in increasing the income of cattle and poultry farmers in India.	102.00	476.604	.748	.946
High-quality and affordable feed is not available for poultry and cattle farmers in my region.	102.15	490.707	.441	.949
Accessibility to reliable suppliers and retailers of feed is poor.	101.93	482.364	.631	.947
Storing and preserving the feed is quite challenging on my farm.	101.97	482.071	.640	.947
Limited access to grazing land is a major problem in my area, especially for cattle farmers.	102.07	478.078	.697	.946
The availability of high-quality breeding stock (e.g., bulls, hens) is quite difficult in my region.	102.31	489.129	.499	.948
There is not enough information among farmers for effective decision-making regarding the breeding of the animals.	102.11	487.164	.528	.948

Access to artificial insemination is limited.	101.79	483.182	.666	.946
Access to government-funded breeding programs is very limited.	101.87	476.274	.753	.946
It is difficult to maintain housing for domesticated birds.	101.88	472.836	.760	.945
Predator attack on the domesticated birds is a major concern among the farmers.	101.96	474.192	.747	.946
Pest and parasite control is quite challenging in bird farming.	101.79	481.080	.627	.947
The availability of effective vaccines is a major barrier to disease prevention among domesticated birds.	101.80	479.668	.519	.948
Limited access to qualified veterinary doctors is a major barrier for farming healthy animals.	101.79	480.591	.629	.947
Access to diagnostic services for cattle and birds is very limited.	101.77	481.366	.644	.947
I can easily identify early signs of disease among poultry birds/cattle.	101.65	485.750	.603	.947
Limited knowledge about cattle/bird illness among farmers is a major barrier.	101.65	479.393	.703	.946
Cost of veterinary care and medication as a barrier to seeking	101.70	483.789	.630	.947

timely healthcare for domesticated birds and cattle.				
A shortage of veterinary doctors is a significant constraint in accessing veterinary care for cattle/birds.	101.76	476.401	.718	.946
It is hard to find veterinary clinics or hospitals.	102.31	513.380	.011	.953
The geographical distance to veterinary clinics that are equipped with necessary services is a major barrier when seeking to deal with sick or injured animals.	102.26	506.187	.138	.952

Table 4.18 Item Total Statistics

The 30-question survey demonstrated a Cronbach's Alpha value of 0.949, indicating a strong level of internal consistency in the participants' responses. This suggests that the tool used was highly dependable in assessing the key areas of sustainable feed production, governmental assistance, breeding-related issues, and veterinary care. In the context of social science studies, an Alpha value exceeding 0.7 is considered satisfactory, while values over 0.9 are typically seen as indicating outstanding reliability. Therefore, the Alpha value obtained is 0.949, and the results show that the questions of this survey will be consistent regarding the measurement of data for the respondents.

Item-Total Statistics

The reliability analysis also allows for insight into the contribution of individual items to the overall consistency of the scale. For each item, "Corrected Item-Total Correlation" and

"Cronbach's Alpha if Item Deleted" were computed, assuming that the removal of any one question would affect the overall reliability of the set.

Highest Correlations: Items like "It is difficult to maintain housing for domesticated birds" (Corrected Item-Total Correlation = 0.760) and "Access to government-funded breeding programs is very limited" (Corrected Item-Total Correlation = 0.753) had the highest corrected item-total correlations. This would suggest that these items were highly correlated with the overall scale and, therefore, contributed very much to the instrument's internal consistency.

Lowest associations were parts like "It is hard to find veterinary clinics or hospitals"Corrected Item-Total Correlation = 0.011 and "The geographical distance to veterinary clinics is a major barrier when seeking to deal with sick or injured animals"Corrected Item-Total Correlation = 0.138. Removing such items would have a slight enhancement in the Cronbach's Alpha, but their contribution was still considered valuable for the content validity of the survey.

4.3 Hypothesis Analysis

4.3.1 Hypothesis 1 Analysis

Null Hypothesis 1: The implementation of sophisticated feed production technology will not enhance the sustainability and effectiveness of feed utilisation in Indian poultry and dairy farms, not resulting in improved economic results for farmers.

Variables Entered/Removeda

Model	Variables Entered	Variables Removed	Method
1	Technology_adoptionb	.	Enter

a. Dependent Variable: Government_Policies
b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.545a	.297	.296	3.85832

a. Predictors: (Constant), Technology_adoption

ANOVA a

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2507.106	1	2507.106	168.413	.000b
	Residual	5924.892	398	14.887		
	Total	8431.997	399			

a. Dependent Variable: Government_Policies

b. Predictors: (Constant), Technology_adoption

Coefficients a

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	6.815	.771		8.840	.000
	Technology_adoption	.853	.066	.545	12.977	.000

a. Dependent Variable: Government_Policies

Table 4.19 Hypothesis 1 Analysis

The regression analysis examined the impact of technology adoption on government policies in Indian poultry and dairy farms. The model showed a moderate correlation ($R = 0.545$) with an R^2 of 0.297, indicating that 29.7% of the variance in government policies is explained by technology adoption. The ANOVA results confirmed significance ($F = 168.413$, $p < 0.001$). The coefficient for technology adoption ($B = 0.853$, $p < 0.001$) suggests a positive impact. Hence, rejecting the null hypothesis, we conclude that sophisticated feed technology enhances sustainability and economic outcomes for farmers.

4.3.2 Hypothesis 2 Analysis

Null Hypothesis 2: Implementing government programs that specifically target the production and distribution of feed will not alleviate the economic strain on Indian poultry and dairy producers, hence does not improve their overall productivity and profitability.

Technology_adoption * Government subsidiaries for Feed and veterinary services help me maintain a sustainable poultry/cattle farm.

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	174.987a	48	.000
Likelihood Ratio	165.796	48	.000
Linear-by-Linear Association	76.741	1	.000
N of Valid Cases	400		

a. 38 cells (58.5%) have expected count less than 5. The minimum expected count is .66.

Technology_adoption * Government regulations on cattle farms are contraning my farm's productivity.

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	318.515a	48	.000
Likelihood Ratio	261.064	48	.000
Linear-by-Linear Association	128.778	1	.000
N of Valid Cases	400		

a. 38 cells (58.5%) have expected count less than 5. The minimum expected count is .57.

Table 4.20 Hypothesis 2 Analysis

The Pearson Chi-Square analysis assessed the relationship between technology adoption and government programs supporting feed production and distribution. The results indicate significant associations ($\chi^2 = 174.987$, df = 48, $p < 0.001$) and ($\chi^2 = 318.515$, df = 48, $p < 0.001$), confirming government subsidies and regulations impact farm sustainability and productivity. The linear-by-linear associations (76.741 and 128.778, $p < 0.001$) further support this. Thus, rejecting the null hypothesis, we conclude that targeted government programs reduce economic strain, improving productivity and profitability for Indian poultry and dairy producers.

4.3.3 Hypothesis 3 Analysis

Null Hypothesis 3: Enhancing the availability of superior feed and veterinary services will not have a beneficial effect on the well-being and efficiency of livestock, thereby does not lead to higher earnings for poultry and dairy producers in India.

Variables Entered/Removeda

Model	Variables Entered	Variables Removed	Method
1	Poverty_Allevationb	.	Enter

a. Dependent Variable: Government_Policies
b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.743a	.552	.551	3.08122

a. Predictors: (Constant), Poverty_Allevation

ANOVAa

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	4653.429	1	4653.429	490.150	.000b
	Residual	3778.569	398	9.494		
	Total	8431.997	399			

a. Dependent Variable: Government_Policies
b. Predictors: (Constant), Poverty_Allevation

Coefficientsa

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	5.055	.540		9.368	.000
	Poverty_Allevation	.678	.031	.743	22.139	.000

a. Dependent Variable: Government_Policies

Table 4.21 Hypothesis 3 Analysis

The regression analysis examined the impact of poverty alleviation on government policies regarding feed and veterinary services in Indian poultry and dairy farms. The model showed a strong correlation ($R = 0.743$) with an R^2 of 0.552, indicating that 55.2% of the variance in government policies is explained by poverty alleviation. ANOVA results confirmed significance ($F = 490.150$, $p < 0.001$). The coefficient for poverty alleviation ($B = 0.678$, $p < 0.001$) suggests a positive impact. Rejecting the null hypothesis, we conclude that superior feed and veterinary services improve livestock efficiency and increase farmers' earnings.

4.3.4 Hypothesis 4 Analysis

Null Hypothesis 4: Introducing training programs and educational activities that specifically target sustainable feed production techniques will not stimulate greater acceptance of these practices among Indian poultry and dairy farmers. Consequently, this will not lead to more effective utilisation of feed and enhanced sustainability of the farms.

Variables Entered/Removeda

Model	Variables Entered	Variables Removed	Method
1	Poverty_Allevationb	.	Enter

a. Dependent Variable: Training

b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.648a	.420	.418	2.24082

a. Predictors: (Constant), Poverty_Allevation

ANOVAa

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1444.822	1	1444.822	287.739	.000b
	Residual	1998.476	398	5.021		
	Total	3443.297	399			

a. Dependent Variable: Training

b. Predictors: (Constant), Poverty_Allevation

Coefficientsa

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	4.974	.392		12.675	.000
	Poverty_Allevation	.378	.022	.648	16.963	.000

a. Dependent Variable: Training

Table 4.22 Hypothesis 4 Analysis

The regression analysis evaluated the effect of poverty alleviation on training programs for sustainable feed production in Indian poultry and dairy farms. The model showed a notable correlation ($R = 0.648$), with an R^2 value of 0.420, suggesting that poverty alleviation accounts for 42% of the variation observed in training programs. ANOVA results confirmed significance ($F = 287.739$, $p < 0.001$). The coefficient for poverty alleviation ($B = 0.378$, $p < 0.001$) highlights its positive impact. Rejecting the null hypothesis, we conclude that targeted training programs enhance feed utilisation and sustainability among farmers.

4.3.5 Hypothesis 5 Analysis

Null Hypothesis 5: Combined traditional and modern feed techniques will not enhance the resilience of the feed production system for Indian poultry and dairy farmers, therefore does not reduce the effects of environmental and economic uncertainty

Training * The frequency of educational programs on new technologies is sufficient to keep farmers updated

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	783.669a	48	.000
Likelihood Ratio	603.866	48	.000
Linear-by-Linear Association	290.413	1	.000
N of Valid Cases	400		

a. 40 cells (61.5%) have expected count less than 5. The minimum expected count is .36.

Training * Government policies promote the availability of superior feed and veterinary services to increased income for the farmers.

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	152.827a	48	.000
Likelihood Ratio	149.361	48	.000
Linear-by-Linear Association	48.606	1	.000
N of Valid Cases	400		

a. 38 cells (58.5%) have expected count less than 5. The minimum expected count is .60.

Training * Government-provided microfinance schemes are effective for cattle and poultry farmers in poverty alleviation efforts.

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	332.624a	48	.000
Likelihood Ratio	260.138	48	.000
Linear-by-Linear Association	123.283	1	.000
N of Valid Cases	400		

a. 40 cells (61.5%) have expected count less than 5. The minimum expected count is .63.

Table 4.23 Hypothesis 5 Analysis

The Pearson Chi-Square analysis assessed the relationship between training and key agricultural policies supporting Indian poultry and dairy farmers. Significant associations were found between training and educational program frequency ($\chi^2 = 783.669$, df = 48, $p < 0.001$), government policies on superior feed and veterinary services ($\chi^2 = 152.827$, df = 48, $p < 0.001$), and microfinance schemes ($\chi^2 = 332.624$, df = 48, $p < 0.001$). Strong linear-by-linear associations further support these findings. Rejecting the null hypothesis, we conclude that integrating traditional and modern feed techniques strengthens resilience, reducing environmental and economic uncertainty.

4.3.5 Discussion of Research Question One

What are the negative uncertainties faced by poultry and cattle farmers in association with feeding, breeding healthcare, and veterinary services?

The first research question focused on the negative uncertainties of poultry and cattle farmers concerning feeding, breeding, healthcare, and veterinary services. It emerged that, on most aspects, farmers face challenges which are interwoven with each other in affecting overall farm sustainability.

Feed availability and its quality were one of the major areas of concern identified in the study. Most of the respondents raised concerns over accessing high-quality and affordable feed, which is of utmost importance in keeping the livestock both healthy and productive. This finding agrees with the results arising from previously related studies, such as Singh and Sharma (2020), who pointed out that feed shortage continues to be a pervasive problem in rural India, especially in the most interior parts where access to reliable suppliers is highly limited. Poor quality of feeds affects the health of the animals, hence bringing down the production output, be it in the form of milk in cattle or eggs and flesh in poultry. Besides that, farmers complained of issues related to storage and preservation as most of them lacked the basic infrastructure to sustain feed quality over time, thus reducing wastage and increasing their expenditure costs. This imperfect feed access, further exacerbated by poor storage options, creates a great deal of uncertainty-one that indeed treads on farming operations.

Other sources of uncertainty identified included breeding services available to the farmers. Most of the respondents reported that there was limited access to superior breeding stock, especially bulls and hens. Suffice it to say that genetically superior breeding stock is a factor of paramount importance in efforts to raise the productivity and health of livestock. These findings were consistent with those by Patil et al. (2018), who indicated that rural farmers often depend on local inferior breeding options because the high cost of superior stock, or an absence of any government-funded breeding program, made access difficult. Further, AI services, essential for improving the genetic potential of the existing stock, are not widely available. The restricted availability of artificial insemination (AI) services stems from a lack of skilled personnel and inadequate infrastructure in rural and remote locations. This increases unpredictability in breeding outcomes, making it difficult for farmers to enhance the quality of their livestock over time.

Besides the basic matters, another major uncertainty facing farmers is that of healthcare and veterinary services. Veterinary care is essential for ensuring animal health and preventing disease outbreaks. Despite its importance, availability of these services remains limited, particularly in rural communities. About 37.8% of the respondents in this study agreed that the cost of veterinary treatment was one of the main factors hindering them from seeking healthcare for their animals in time, while 38.3 percent identified the lack of veterinary personnel. The inadequacy and lack of trained veterinarians also mean that the treatment cost is rather high, which most farmers cannot afford. This often affects the mortality rate and productivity level of a farmer's animal. As a fact, diagnostic services, which are of importance in early disease detection, are extremely limited, adding to the health uncertainty of the animals even more. Another critical issue is the availability of vaccines and preventive care that are key in preventing the outbreak of diseases among the animals. Most farmers reported difficulties in obtaining the vaccines, and 37% agreed that availability of effective vaccines remains a major barrier to preventing diseases in livestock. Singh & Sharma, 2020. Lack of access to these preventive measures puts the animals at great risk of being affected by diseases, thus devastating results affecting even the whole farm. Beyond the perspective of increasing mortality rates, insufficient preventive health care in livestock carries real long-term economic costs for farmers who cannot afford to replace lost animals or treat diseases that could be prevented with proper vaccinations.

4.3.6 Discussion of Research Question Two

What are the government policies that are and should be framed in favour of poultry and cattle farmers?

The second research question focused on the identification of existing government policies that benefit poultry and cattle farmers and the additional policies that should be framed in order to provide more help to these farmers. It appeared from the study that although there were a lot of government programs which were offering the necessary amount of assistance, there were certain areas in which more specific policies needed to be drawn and implemented for taking off the pressure from the farmers' shoulders.

One of the major policies on which the farmers operate is financial support, such as subsidies and loans. In this respect, the government's financial assistance was adequate to adopt new technologies, as 32.5% of the respondents in the current study agreed to the fact, while 34.5% strongly agreed (Pandey & Singh, 2019). Financial assistance aids the farmers in undertaking resource-conserving farming practices like feed production and bears the expenses related to veterinary care and breeding services. Even with community-level funds, bureaucratic obstacles often impede access for many small-scale farmers from remote areas. Scaling up financial programs that ensure wider access, coupled with simplification of the application process, would be salient steps both to make access to this policy more effective.

The other major act the government has taken is providing tax exemptions for agricultural activities. Tax benefits reduce the operational expenses for farmers, who can then use that extra money to buy better feed and utilize the latest breeding technologies. Kumar & Joshi, 37.8% of the total respondents believed that tax exemption helped them significantly in expanding their farms. Full potentiality of benefits is hampered due to a lack of awareness among farmers, especially in rural areas. More farmers should reap the benefits of such a policy; hence, the government should create more awareness and make access to information on tax exemption easier.

Government assistance is further extended to veterinary services and vaccination programs. Vaccination drives by the government are a necessity in preventing diseases among livestock and maintaining herd health. About 28.8% of the total respondents acknowledged the contribution of government-funded vaccination programs to keeping their animals healthy. However, most farmers indeed confirm the limitation in access to veterinary services, particularly in rural areas, where the shortage of veterinary professionals and high treatment costs are the main issues.

Ensuring better veterinary infrastructure, increased government-funded veterinarians, and mobile veterinary services would help ensure more access to care and reduce some 'guessing games' related to animal health management (Singh & Sharma, 2020).

The study indeed showed some positive outlooks regarding the skill development programs. In this case, this would entail training on modern farming techniques, besides sustainable ways of producing feed, thereby bringing improvement in the farmers' productivity. About 37.8% stated that the programs had increased their incomes. These programs have small coverage, with very minimal coverage in the most remote areas. Increased access to knowledge and skills among more farmers is possible with expanded training through online platforms and peer-to-peer learning initiatives. These supportive policies have resulted in a large gap in breeding services. Most of the farmers have access to poor-quality breeding stock, and AI services are also limited. Consequently, improvement in livestock productivity is restricted. In this regard, subsidized access to superior breeding stock and AI services through government-funded programs could be highly advantageous for farmers. It is also suggested that the gap in breeding services can be filled up through investment in the research and development of breeding technologies.

4.3.7 Discussion of Research Question Three

What are the strategies adopted to educate and implement new technologies in poultry and cattle farming?

The third research question was set to identify some of the adopted strategies to educate the poultry and cattle farmer about new technologies and their implementation schema in the farming process. In agreement with expectations, education and training processes, government initiatives, and peer-to-peer learning were the most dominant strategies used in educating farmers on technological adoption in farm operations.

One of the major strategies identified is the implementation of government-sponsored skill development programs. Such programs give training to farmers in modern methods of farming, sustainable and nutritive feed production, and improved management of their livestock. As many as 37.8% of the total respondents came to agree that they were assisted by the programs in increasing their income with the help of better farming techniques. Organized workshops and hands-on training sessions are facilitated through schemes launched by the government, including the National Livestock Mission and Krishi Vigyan Kendras.

These programs target a wide range of farmers, most especially in rural areas, so that they may be adequately prepared for the many challenges posed by modern livestock farming.

While all these programs have been highly appreciated, access is still unequal, especially for small-scale farmers and those in very remote areas. Indeed, most respondents mentioned that, while government-sponsored training programs offer an advantage, they are only located in the well-developed areas of the country. Increasing geographical coverage, and using mobile training units could help extend the reach so that farmers from poorer regions might also benefit, Singh & Sharma 2020. Another very important approach to informing farmers about new technologies is learning by peers. Farmers indirectly learn from other farmers through sharing experiences and best practices. Such a process reflects informal learning, which is crucial for spreading technology, particularly in rural areas where access to structured training opportunities is often scarce.

In many cases, farmers believe in advice provided by other farmers who have already successfully adopted certain new technologies, such as automated feed systems or enhanced breeding techniques. This exchange of information is often facilitated through farmer cooperatives or local agricultural associations, which create a support network that fosters the adoption of modern practices.

This is, however, the limitation of peer-to-peer learning while highly effective. The knowledge shared here is many times personal experiences and may not be the most efficient or scientifically validated approach. Hence, integrating the same with formal training programs would provide a comprehensive solution wherein farmers would also get practical advice but scientifically grounded. Other significant approaches to giving knowledge to these farmers include the use of digital platforms and mobile applications. Within the past couple of years, there is development in some digital tools that would provide the farmers with real-time information on aspects like livestock management, prevention of diseases, and even market trends. Further, different mobile applications, such as "Pashu Poshan", among others, helped farmers in consultations, weather forecasting, veterinary care, and knowledge that, in turn, helped in decision-making (Kumar & Joshi, 2019). Such applications are especially useful in areas where access to a physical network of training sites is very limited.

It also emerged that the relatively younger farmers, in particular, were more inclined to use mobile apps and other digital platforms in farm management, hence marking a generational shift to tech-based solutions.

While implementing these digital strategies, one of the major challenges is certainly digital illiteracy among aging farmers. While a young farmer is quite adept at using technology, an older one may have problems taming these tools, which are absolute in their effectiveness. Training programs should therefore include the element of digital literacy in their curricula, making sure that each farmer, whatever the age may be, can use digital innovations in farming.

4.4 Summary of Findings

The present study has tried to explore the challenges and opportunities pertaining to sustainable feed production, government support, breeding services, and veterinary care for Indian poultry and dairy farmers. Based on the analysis, a few broader implications have been drawn that delineate the current state of these sectors and point toward areas that need attention for better sustainability and economic performance.

The demographic study reveals that most of the participating couples belonged to the economically active age range of 31 to 40 years, with a fairly balanced ratio between males and females. Almost all farmers were at least secondary educated, which is an encouraging sign for the adoption of modern farming practices. However, income disparities manifest themselves in such a way that the large group of farmers belongs to very low-income classes, which limits their investment in new technologies and sustainable practices.

In fact, one of the major challenges that were noted in the study is non-availability of quality and cheap feed. Most respondents reported difficulties in accessing reliable feed suppliers with poor storage and preservation facilities aggravating the problem further. Land availability for open grazing has also emerged as one of the major constraints, more so among the cattle farmers. All these challenges signal that there is a dire need to enhance the infrastructure and supply chain management functions so that farmers have all the resources available for sustainable livestock farming.

The breeding and veterinary services were noted as critical areas of concern. A high proportion of the respondents reported difficulty in accessing high-quality breeding stock and artificial insemination services-both very critical in advancing productivity in livestock.

In addition to this, the lack of veterinary professionals and high veterinary costs were significant challenges to sustaining the health of the animals. Farmers also felt that diagnostic services were extremely limited, as was access to preventative measures such as vaccinations, which is why disease management persisted for so many farmers.

Most of the respondents appreciated the various government support programs, especially those offering financial assistance, tax exemptions, and skill development programs. On the other hand, there were also responses that showed difficulties in accessing such resources, especially in rural and under-served areas. While some farmers have benefited from these programs, others continue to face barriers, indicating the need for expanded and more accessible government initiatives. On the whole, positive developments on most sustainable feed production and governmental support are nullified by serious challenges on resource access, veterinary services, and breeding services. Such issues will have to be sorted out if there is to be long-term sustainability and growth in the poultry and dairy farming sectors.

The study tested five hypotheses on the impact of feed production technology, government programs, and training on Indian poultry and dairy farming. Regression and Chi-Square analyses confirmed significant relationships across all variables. Technology adoption improved sustainability and economic outcomes ($R^2 = 0.297$, $p < 0.001$). Government programs reduced economic strain, enhancing productivity ($\chi^2 = 174.987$, $p < 0.001$). Superior feed and veterinary services improved livestock efficiency and farmer earnings ($R^2 = 0.552$, $p < 0.001$). Training programs increased sustainable feed adoption ($R^2 = 0.420$, $p < 0.001$). Combining modern and traditional feed techniques strengthened resilience, reducing uncertainty ($\chi^2 = 783.669$, $p < 0.001$). All null hypotheses were rejected.

The study looked into the challenges facing farmers in poultry and cattle production, the role of government policies, and strategies for adopting new technologies. There is a high level of uncertainty in feeding, breeding, healthcare, and veterinary services. Availability of quality feed at affordable prices remains the most important issue, besides the lack of appropriate storage facilities, which results in wastage and increased costs. Challenges in breeding include limited availability of superior stock and AI services because of financial constraints and lack of proper infrastructure. Veterinary services are a cost, which is on the higher side, and also the preventive measures, such as vaccination, are not very prominent. This results in high mortality and low productivity. Government policies, like financial assistance, tax exemption, and vaccination programs, give some relief. However, their effectiveness is hindered by bureaucratic obstacles and a lack of awareness, mainly in rural areas.

CHAPTER 5

DISCUSSIONS, CONCLUSIONS, AND IMPLICATIONS

5.1 Introduction

This chapter concludes the study by summarizing its key findings, drawing final insights, and highlighting the broader implications for policy, practice, and research. The investigation focused on the challenges faced by Indian poultry and dairy farmers, particularly in relation to sustainable feed production, veterinary services, breeding practices, and government interventions. Through a combination of primary data analysis and literature review, the study identified critical factors influencing livestock productivity and economic outcomes. Through the combined use of regression and Chi-Square analysis, the study validated the strong influence of technology adoption, supportive policies, and training programs. This section also outlines the study's implications, addresses its limitations, and offers recommendations for future research and policy planning.

5.2 Summary of the study and findings conclusions

The study systematically examined the challenges and opportunities encountered by poultry and cattle farmers in India, particularly in relation to sustainable feed production, breeding services, veterinary care, and the role of government policies. Key issues identified include the unavailability of quality feed, inadequate veterinary services, and challenges in breeding practices. Farmers, particularly in rural areas, often lack access to essential resources, resulting in compromised livestock productivity. While various government initiatives—such as financial assistance, tax exemptions, and training programs—have enabled some farmers to diversify and adopt advanced technologies, these programs remain unevenly distributed, particularly in remote regions. The research emphasized the importance of education, skill development, collaborative learning, and digital tools in promoting the use of advanced agricultural practices.

To assess the effectiveness of interventions, the study conducted hypothesis testing using regression and Chi-Square analyses, confirming significant relationships across all variables. Technology adoption was found to enhance sustainability and economic outcomes ($R^2 = 0.297$, $p < 0.001$). Government programs alleviated economic strain and improved productivity (χ^2 =

174.987, $p < 0.001$). The availability of superior feed and veterinary services contributed to improved livestock efficiency and farmer earnings ($R^2 = 0.552$, $p < 0.001$). Training initiatives increased sustainable feed adoption ($R^2 = 0.420$, $p < 0.001$), while integrating modern and traditional feed techniques enhanced resilience, mitigating environmental and economic uncertainties ($\chi^2 = 783.669$, $p < 0.001$). All null hypotheses were rejected.

Despite progress in promoting sustainable farming practices, significant gaps remain in resource availability, veterinary support, and the coverage of government programs. Addressing these gaps requires enhanced access to resources, improved infrastructure, and targeted policy interventions. The findings underscore the need for continuous policy refinement and the implementation of inclusive strategies to support farmers, particularly in underserved regions, ensuring the long-term sustainability and growth of India's poultry and dairy sectors.

5.3 Implications and Applications Future Research

This study contributes significantly to both academic discourse and practical applications within the poultry and dairy farming industry in India. From an academic perspective, the research advances existing literature on sustainable livestock farming by providing empirical evidence on the impact of feed production technology, veterinary care, training programs, and government policies on farm sustainability and economic outcomes. The findings reinforce the relevance of agricultural extension theories, technology adoption models, and rural development frameworks, offering a nuanced understanding of how external interventions influence farming practices. Additionally, the study provides a methodological contribution by employing both regression and Chi-Square analyses, enabling a robust examination of relationships between key variables. Future researchers can build upon this foundation to explore deeper causal linkages and assess long-term impacts.

For the industry, the study underscores the critical role of integrating modern feed production techniques, veterinary services, and training initiatives to enhance farm resilience and productivity. Agribusiness companies, veterinary service providers, and feed manufacturers can leverage these insights to tailor their products and services to meet the needs of farmers, particularly in underserved areas. The findings also hold implications for financial institutions, as they highlight the importance of accessible microfinance schemes in improving farm productivity. The study further informs non-governmental organisations (NGOs) and rural development agencies on the importance of peer-to-peer learning models and digital platforms in knowledge dissemination. Additionally, policymakers can use these insights to refine existing agricultural policies, ensuring equitable access to resources and capacity-building initiatives. The research thus serves as a bridge between academia and industry, offering evidence-based recommendations that can shape the future of sustainable poultry and dairy farming in India. By addressing key challenges faced by farmers, this study provides a roadmap for fostering a more resilient, economically viable, and environmentally sustainable livestock sector.

5.3.2 **Recommendations**

Based on the findings, targeted recommendations are provided for key stakeholders, including policymakers, researchers, and industry practitioners.

For policymakers, the study suggests enhancing the accessibility and coverage of government support programs, particularly in remote areas. This can be achieved by establishing rural extension centres that provide real-time veterinary support, access to superior feed, and training in sustainable farming techniques. Additionally, agricultural subsidies should be restructured to incentivise the adoption of advanced feed production technologies. Policies should also encourage public-private partnerships to facilitate research and innovation in sustainable livestock farming. Furthermore, integrating digital platforms into government extension services can ensure wider outreach and real-time advisory support to farmers.

For researchers, this study highlights the need for further exploration of the long-term impacts of sustainable feed production techniques and training interventions on farm profitability. Upcoming studies should consider using long-term research approaches to evaluate how well these initiatives hold up over extended periods. Moreover, it is important to conduct cross-disciplinary research that explores how agriculture, technological advancements, and economic factors interact within the field of livestock management. Researchers should also explore the socio-cultural barriers to technology adoption, providing insights into how behavioural change models can be leveraged to enhance acceptance among farmers.

For industry practitioners, including feed manufacturers, veterinary service providers, and agribusiness firms, the findings suggest an urgent need for product innovation tailored to small-scale farmers. Companies should invest in cost-effective and locally adaptable feed production technologies to increase affordability and accessibility. Additionally, industry players should collaborate with training institutions to develop structured educational programs that equip farmers with the necessary technical skills. Expanding microfinance services tailored to smallholder farmers can also enhance their capacity to invest in improved farming inputs. By aligning business strategies with sustainability goals, industry stakeholders can drive long-term growth in the livestock sector while ensuring economic viability for farmers.

5.4 Conclusion

This study has provided valuable insights into the challenges and opportunities in India's poultry and dairy farming sector, particularly regarding sustainable feed production, veterinary services, training, and government policies. The findings confirm that targeted interventions in these areas significantly enhance farm productivity, economic resilience, and sustainability. While government programs have played a role in alleviating financial constraints and promoting technological adoption, disparities in access persist, particularly in rural areas. This study highlights the importance of collaborative efforts among policymakers, academics, and industry professionals to close current gaps and support inclusive development.

Moving forward, sustainable livestock farming in India will require greater integration of modern feed techniques, enhanced veterinary infrastructure, and widespread training initiatives. Policy reforms, innovative industry solutions, and academic research must align to create a resilient agricultural ecosystem that supports both smallholder farmers and large-scale producers. Ultimately, by addressing the structural barriers limiting resource access and knowledge dissemination, India can strengthen its livestock sector, ensuring long-term economic stability and food security. The study’s findings and recommendations thus serve as a strategic guide for shaping future agricultural policies and industry practices, with the overarching goal of fostering sustainable and equitable growth in the poultry and dairy sectors.

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APPENDIX A

Questionnaire Development

On

Navigating Uncertainties Towards Sustainable Feed Production for Indian Poultry and Cattle Farmers

This questionnaire is framed to collect appropriate information from dairy and poultry farmers in India regarding how government policies help in poverty alleviation. More specifically, this questionnaire intends to collect pertinent information from these respondents on what are the constraints they face in their operations and the major challenges associated with them. The opinion poll available beneath is a tool selected for gathering data for the investigation titled **"Navigating Uncertainties Towards Sustainable Feed Production for Indian Poultry and Cattle Farmers".** The contributor are called to answer earnestly to all of the below-mentioned questions. The participants are assured that their information will be strictly kept confidential and utilized exclusively for research purposes.

Part A Demographic Details:

1. Age Group (in Years):

    Under 18

    18-30

    31-40

    41-50

    51-60

    Above 60

2. Gender

    Male

    Female

    None-Binary

    Prefer not to disclose

3. Education Qualification

No education
Primary Education
Secondary Education
Diploma
Graduation or above.

4. Marital Status:

Single
Married
Divorced
Widowed
Separated

5. Yearly Household Income

Less than ₹2,00,000
₹2,00,000 - ₹4,99,999
₹5,00,000 - ₹9,99,999
₹10,00,000 - ₹14,99,999
₹15,00,000 - ₹19,99,999
₹20,00,000 or more
Prefer not to Disclose

6. Number of Family Members

1-3
4-6
7-9
10-12
13-15
More than 15.

7. I am a:

Cattle Farmer
Poultry Farmer
Both

Part B: Government Policies Encouraging Poultry and Dairy Farming

Using a scale of 1 to 5, kindly rate how much do you align with the provided statements based on your experience. (SD = Strongly Disagree, D = Disagree, A = Agree, N = Neutral, SA = Strongly Agree)

Statements	SD	D	N	A	SA
1. Tax exemption in farming activities plays a significant role in the growth of cattle/poultry farms in India.					
2. Government-funded vaccination drives play an important role in maintaining the health of farm animals.					
3. Government subsidiaries for Feed and veterinary services help me maintain a sustainable poultry/cattle farm.					
4. Government policies promote fair market access and pricing for poultry/dairy products, leading to increased income for the farmers.					
5. Government regulations on cattle farms are contraning my farm's productivity.					

Part C: Poverty Alleviation

Using a scale of 1 to 5, kindly rate how much do you align with the provided statements based on your experience. (SD = Strongly Disagree, D = Disagree, A = Agree, N = Neutral, SA = Strongly Agree)

Statements	SD	D	N	A	SA
6. Government-provided microfinance schemes are effective for cattle and poultry farmers in poverty alleviation efforts.					
7. Government policies promote inclusive and equal opportunities for marginalized groups within cattle and poultry farmers.					
8. Government-provided financial assistance programs contribute to the alleviation of					

poverty among cattle and poultry farmers.					
9. The government is effectively addressing the infrastructure-related issues (access to water, roads, and electricity) that affect the livelihood of poor farmers.					
10. Government-sponsored skill development programs help in increasing the income of cattle and poultry farmers in India.					

Part D: Challenges and Obstacles Encountered by Poultry and Dairy Farmers

Using a scale of 1 to 5, kindly rate how much do you align with the provided statements based on your experience. (SD = Strongly Disagree, D = Disagree, A = Agree, N = Neutral, SA = Strongly Agree)

Statements	SD	D	N	A	SA
Feeding					
11. High-quality and affordable feed is not available for poultry and cattle farmers in my region.					
12. Accessibility to reliable suppliers and retailers of feed is poor.					
13. Storing and preserving the feed is quite challenging on my farm.					
14. Limited access to grazing land is a major problem in my area, especially for cattle farmers.					
Breeding					
15. The availability of high-quality breeding stock (e.g., bulls, hens) is quite difficult in my region.					
16. There is not enough information among farmers for effective decision-making regarding the breeding of the animals.					
17. Access to artificial insemination is limited.					

18. Access to government-funded breeding programs is very limited.					
Domesticated birds					
19. It is difficult to maintain housing for domesticated birds.					
20. Predator attack on the domesticated birds is a major concern among the farmers.					
21. Pest and parasite control is quite challenging in bird farming.					
22. The availability of effective vaccines is a major barrier to disease prevention among domesticated birds.					
Health care,					
23. Limited access to qualified veterinary doctors is a major barrier for farming healthy animals.					
24. Access to diagnostic services for cattle and birds is very limited.					
25. I can easily identify early signs of disease among poultry birds/cattle.					
26. Limited knowledge about cattle/bird illness among farmers is a major barrier.					
Veterinary Services					
27. Cost of veterinary care and medication as a barrier to seeking timely healthcare for domesticated birds and cattle.					
28. A shortage of veterinary doctors is a significant constraint in accessing veterinary care for cattle/birds.					
29. It is hard to find veterinary clinics or hospitals.					
30. The geographical distance to veterinary					

clinics that are equipped with necessary services is a major barrier when seeking to deal with sick or injured animals.					

Part E: Strategies Adopted for Training and Education

Using a scale of 1 to 5, kindly rate how much do you align with the provided statements based on your experience. (SD = Strongly Disagree, D = Disagree, A = Agree, N = Neutral, SA = Strongly Agree)

Statements	SD	D	N	A	SA
31. The training programs provided are effective in educating farmers about new technologies.					
32. Educational resources (e.g., workshops, seminars, online courses) are easily accessible to farmers.					
33. The frequency of educational programs on new technologies is sufficient to keep farmers updated.					

Part F: Strategies Adopted for Technology Adoption and Implementation

Using a scale of 1 to 5, kindly rate how much do you align with the provided statements based on your experience. (SD = Strongly Disagree, D = Disagree, A = Agree, N = Neutral, SA = Strongly Agree)

Statements	SD	D	N	A	SA
34. The process of adopting new technologies in farming operations is straightforward and well-supported.					
35. Adequate financial support is provided to farmers for implementing new technologies.					
36. Sufficient technical assistance is available to farmers during the implementation of new technologies.					

APPENDIX B

Statistical Analysis of Likert Scale

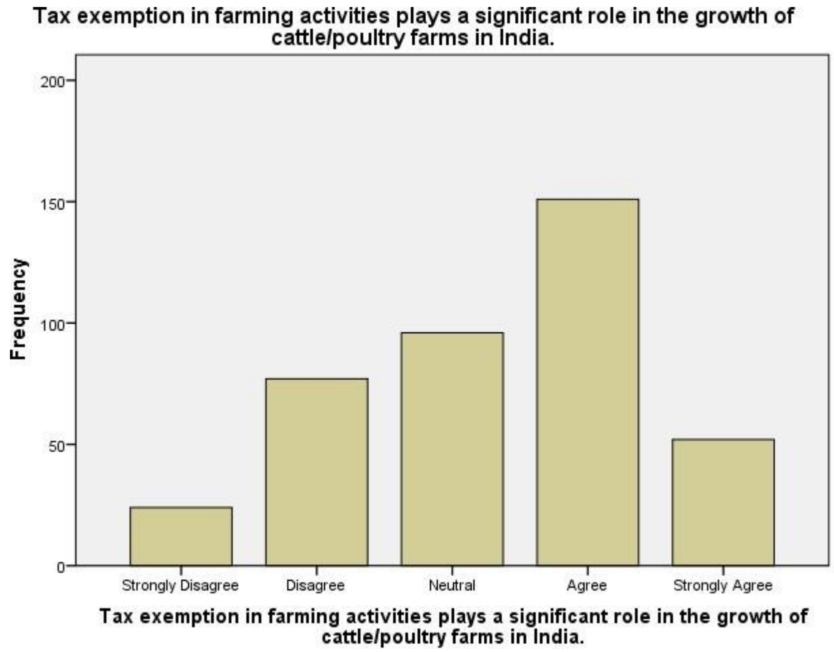

Figure 4.7: Tax exemption in farming activities

37.8% of the population opt for Agree as the response.

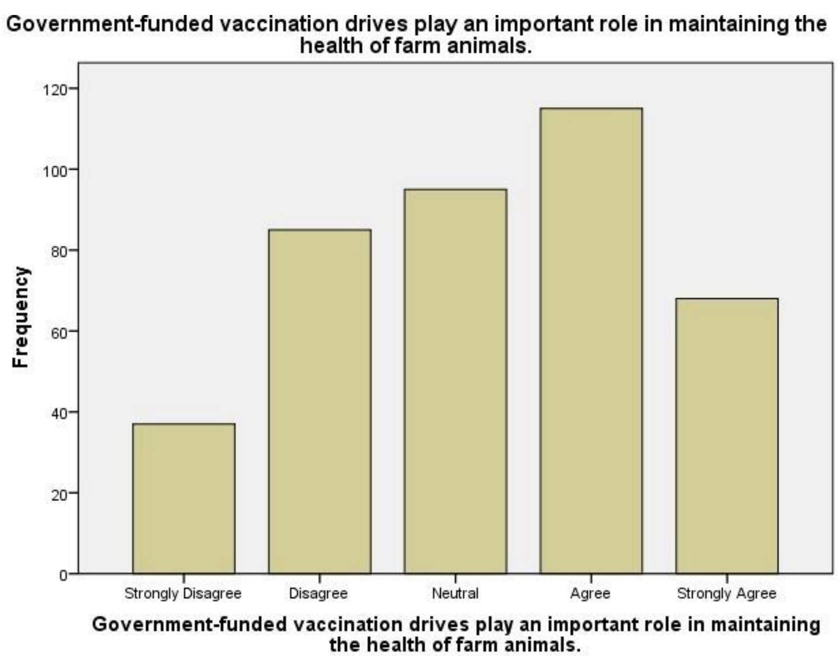

Figure 4.8: Government-funded vaccination

28.8% of the population opt for Agree as the response.

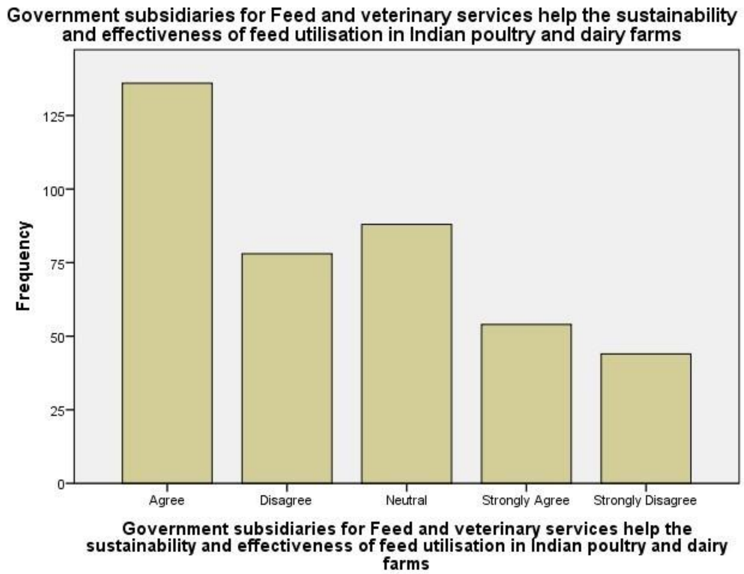

Figure 4.9: Government subsidiaries for Feed and veterinary services

34.0% of the population opt for Agree as the response.

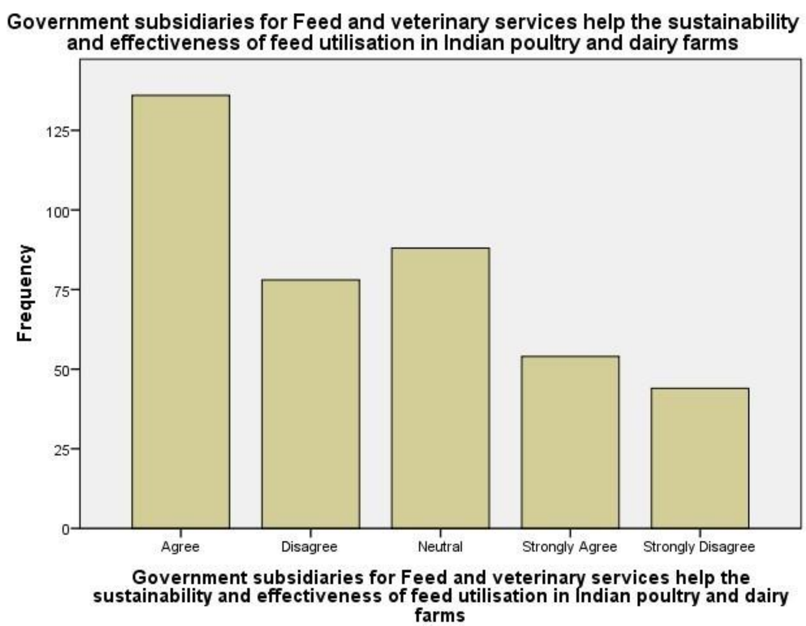

Figure 4.10: Government subsidiaries for Feed and veterinary services

31.8% of the population opt for Agree as the response

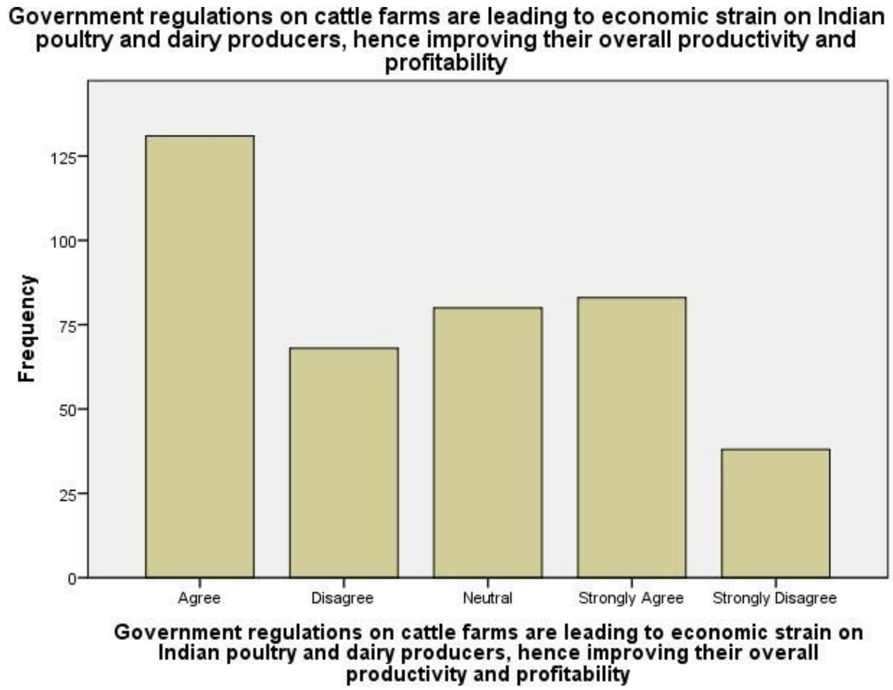

Figure 4.11: Government regulations on cattle farms

32.8% of the population opt for Agree as the response

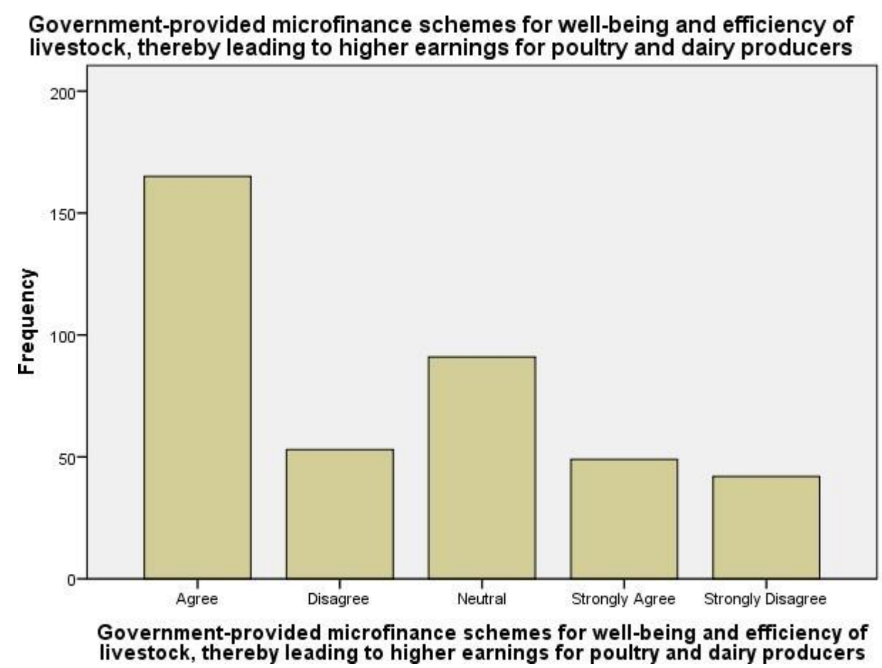

Figure 4.12: Government-provided microfinance schemes
41.3% of the population opt for Agree as the response.

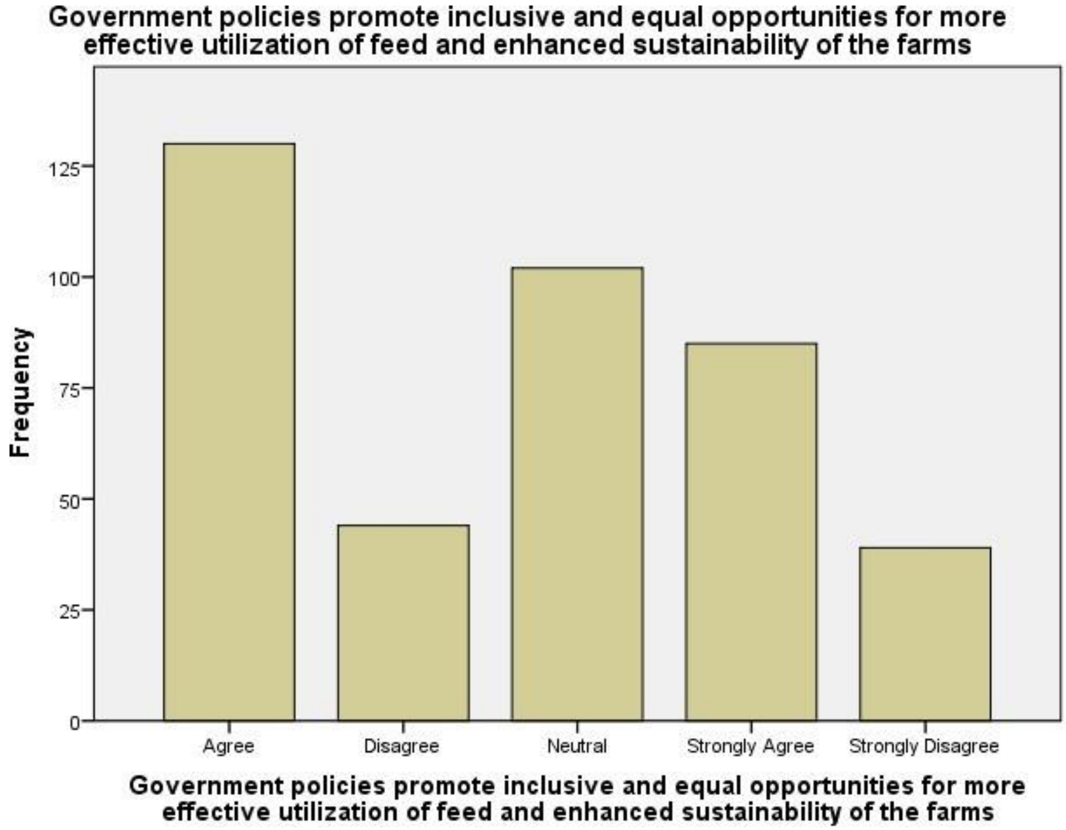

Figure 4.13: Government policies

32.5% of the population opt for Agree as the response

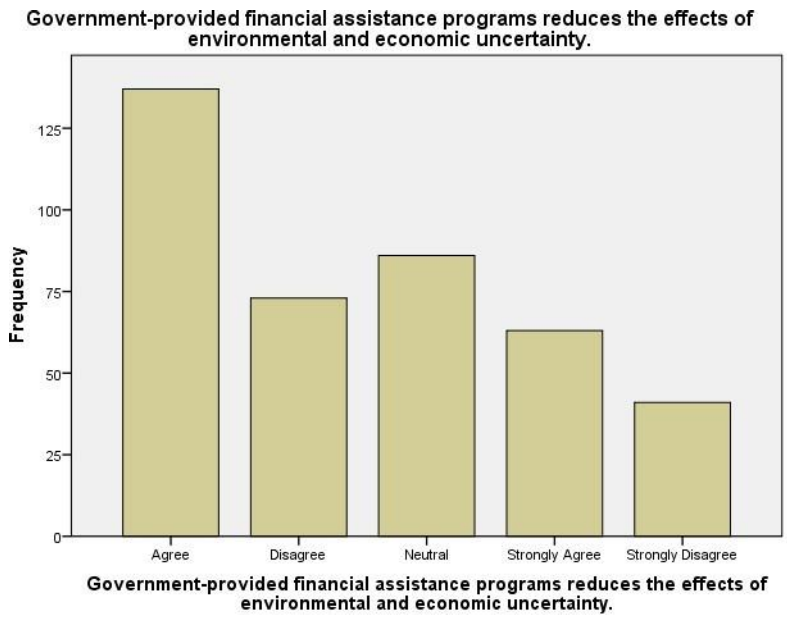

Figure 4.14: Government-provided financial assistance programs

34.3% of the population opt for Agree as the response

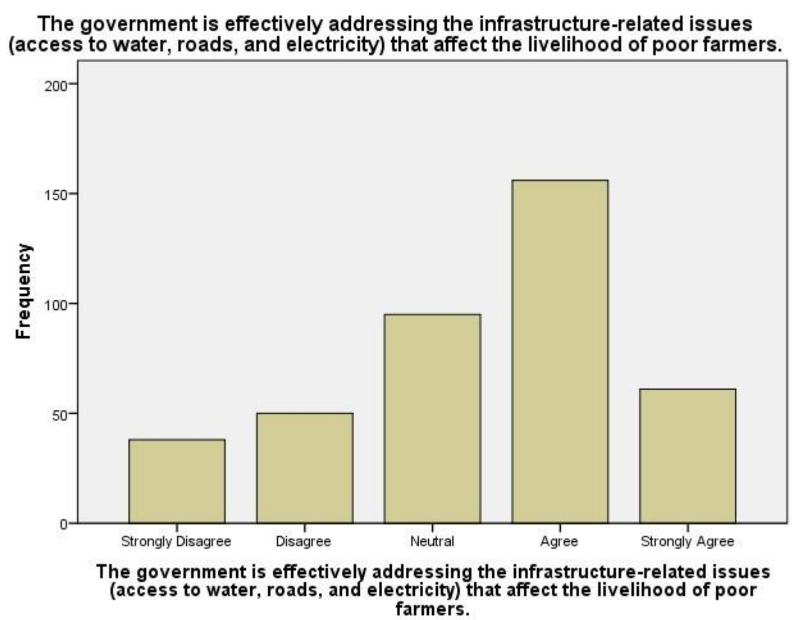

Figure 4.15: Infrastructure-related issues (access to water, roads, and electricity)

39.0% of the population opt for Agree as the response

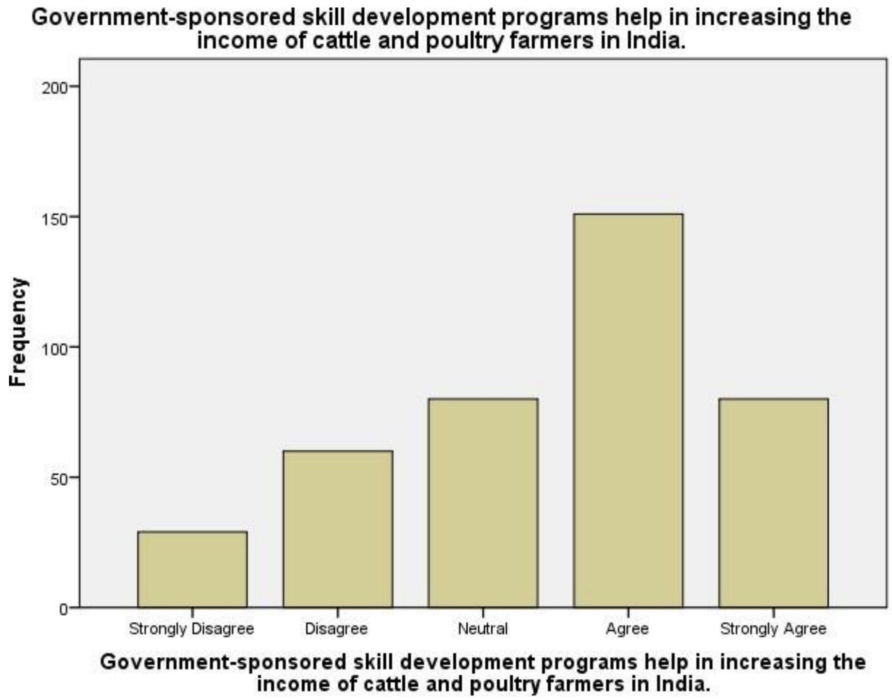

Figure 4.16: Government-sponsored skill development programs
37.8% of the population opt for Agree as the response

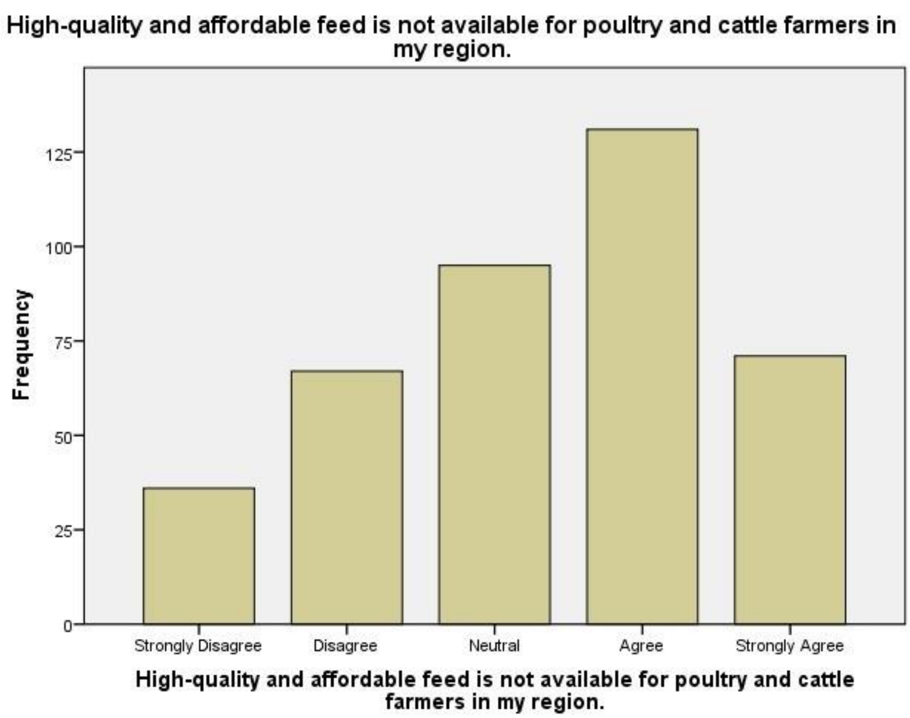

Figure 4.17: High-quality and affordable feed
32.8% of the population opt for Agree as the response

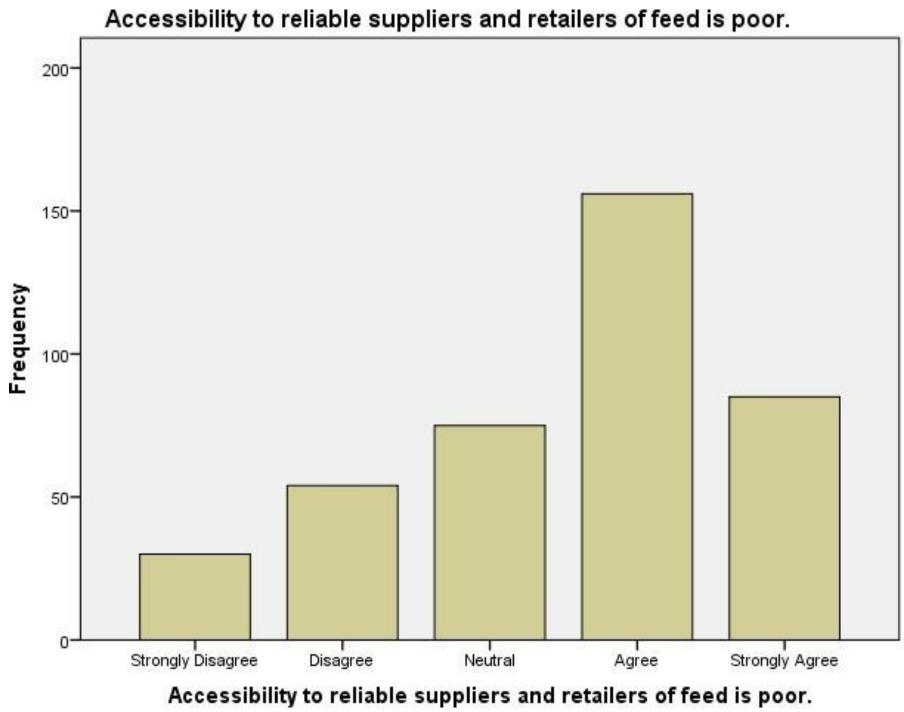

Figure 4.18: Accessibility to reliable suppliers and retailers of feed

39.0% of the population opt for Agree as the response

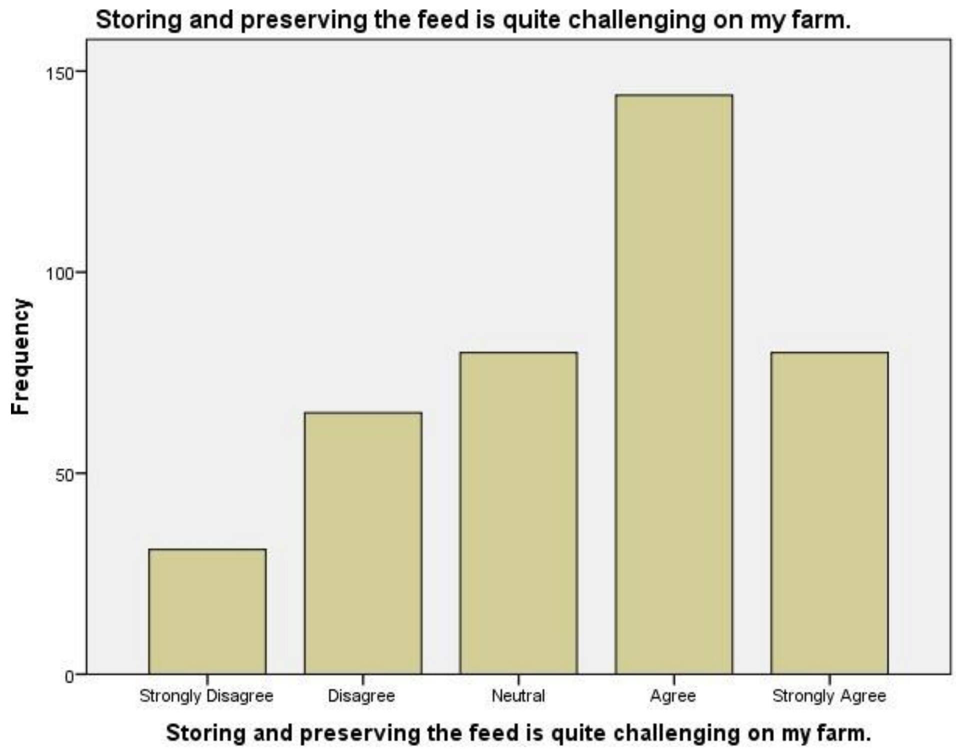

Figure 4.19: Storing and preserving the feed
36.0% of the population opt for Agree as the response

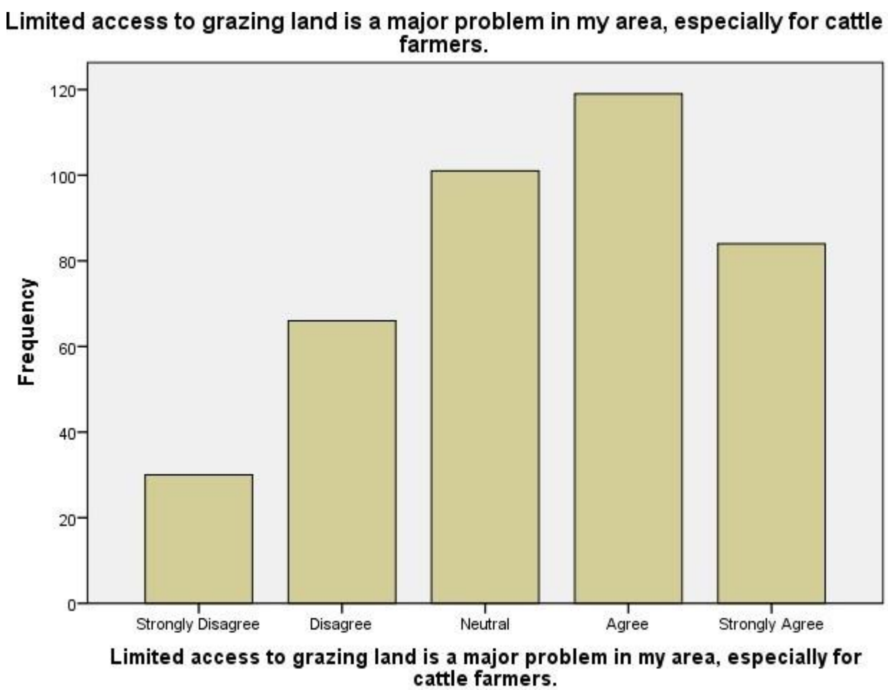

Figure 4.20: Limited access to grazing land
29.8% of the population opt for Agree as the response

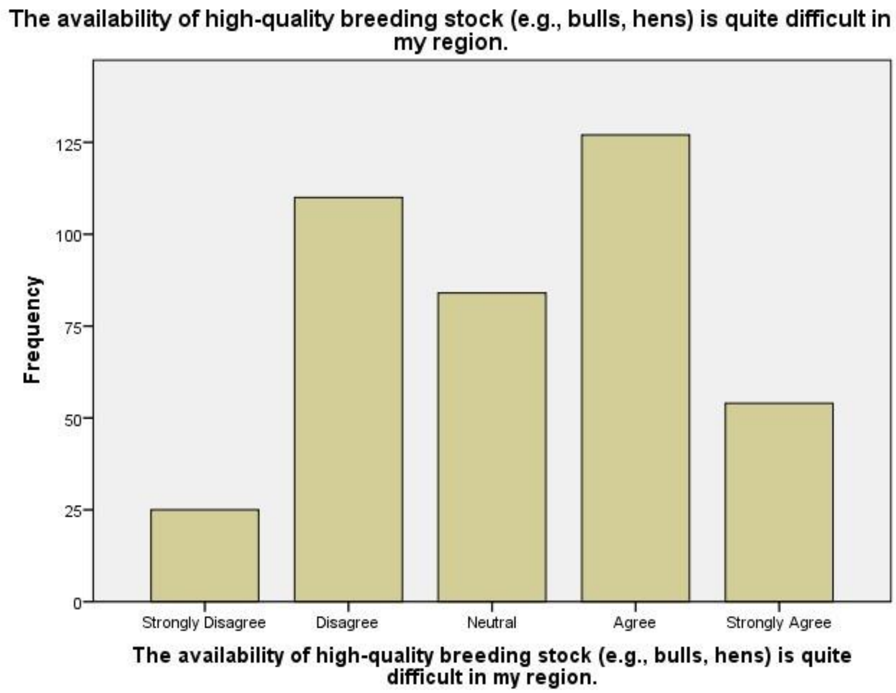

Figure 4.21: The availability of high-quality breeding stock
31.8% of the population opt for Agree as the response

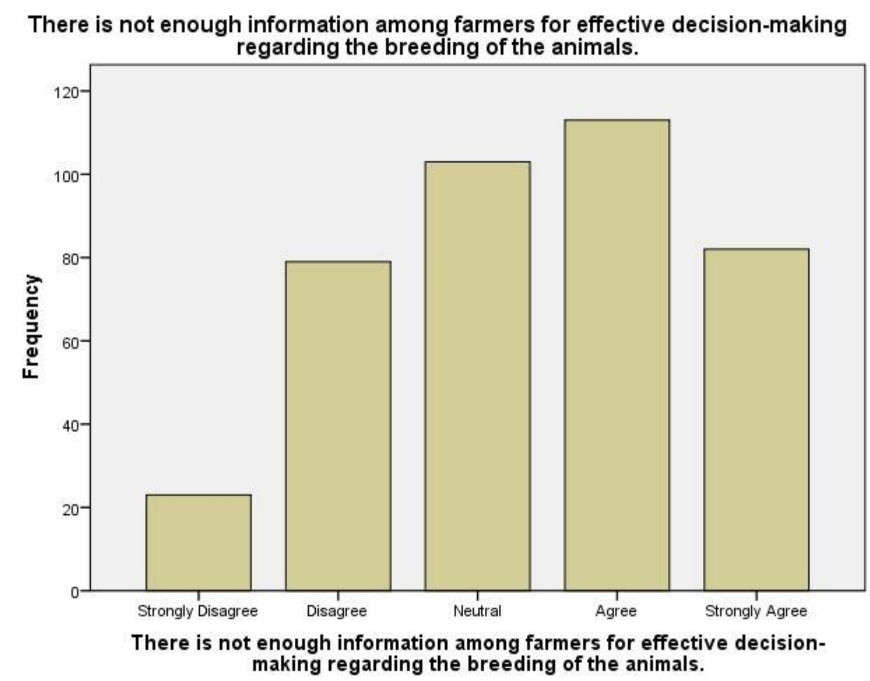

Figure 4.22: Information among farmers for effective decision-making
28.3% of the population opt for Agree as the response

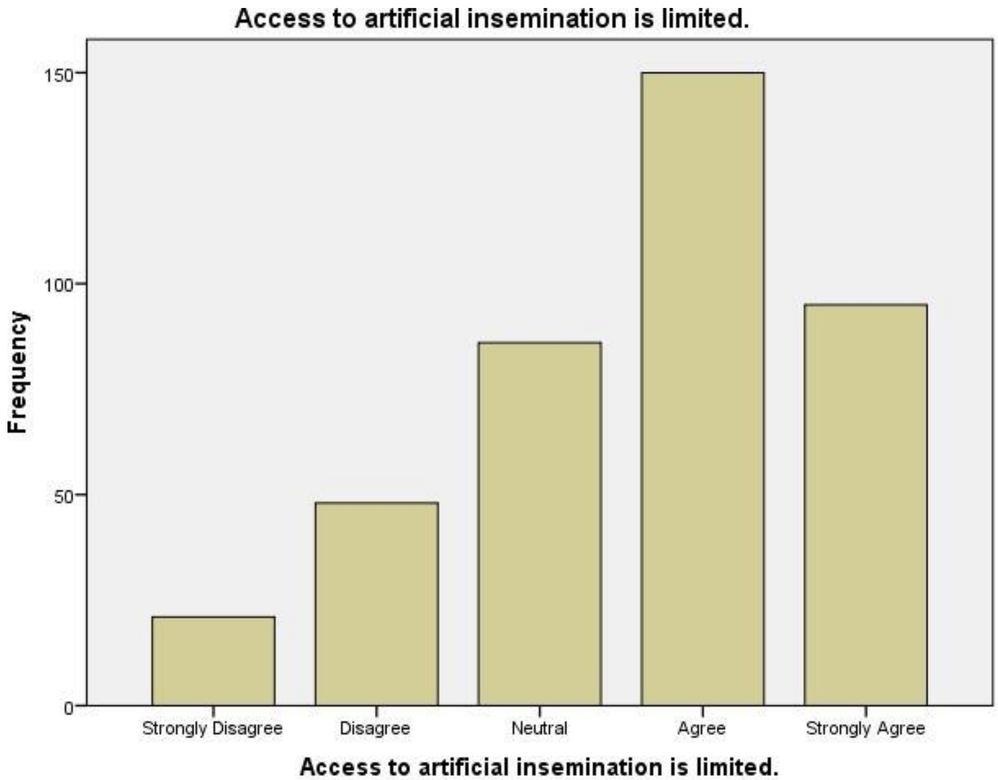

Figure 4.23: Access to artificial insemination

37.5% of the population opt for Agree as the response

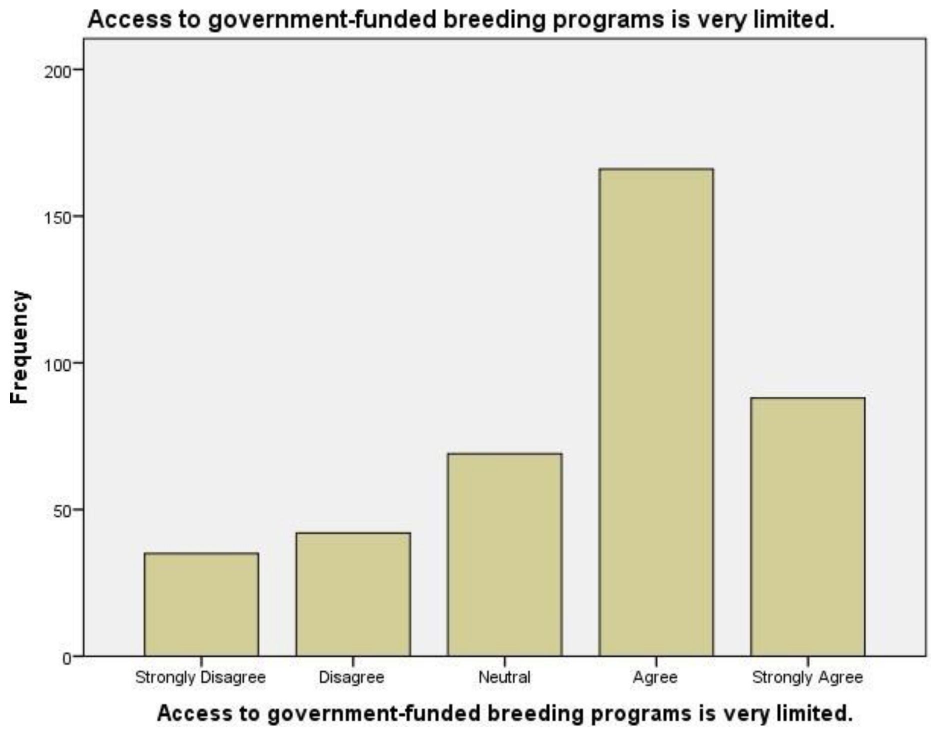

Figure 4.24: Access to government-funded breeding programs

41.5% of the population opt for Agree as the response

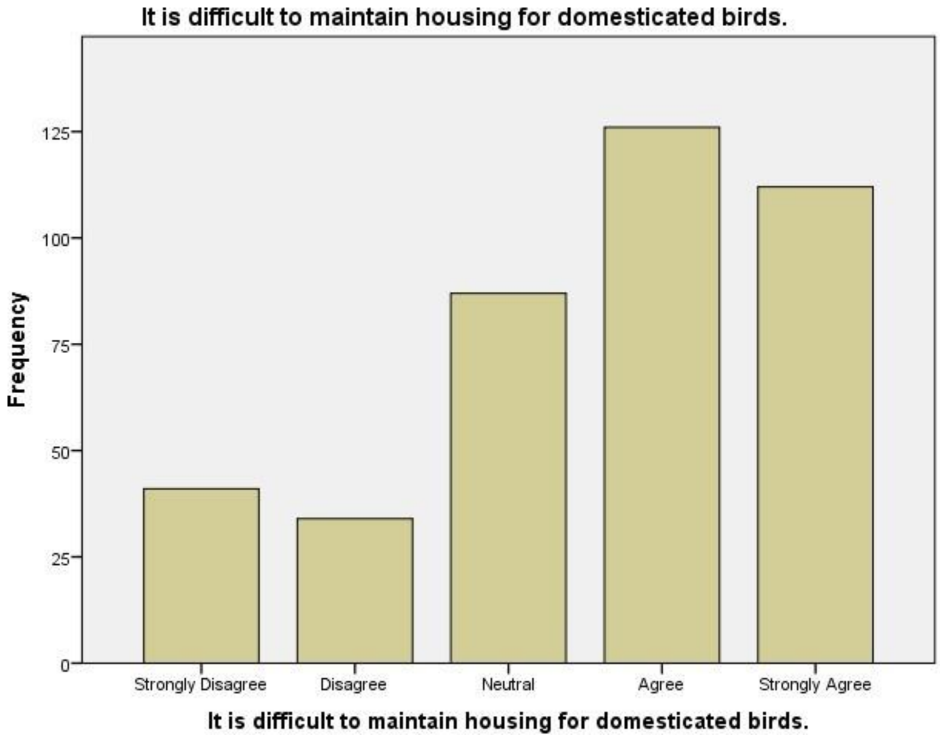

Figure 4.25: Domesticated birds

31.5% of the population opt for Agree as the response

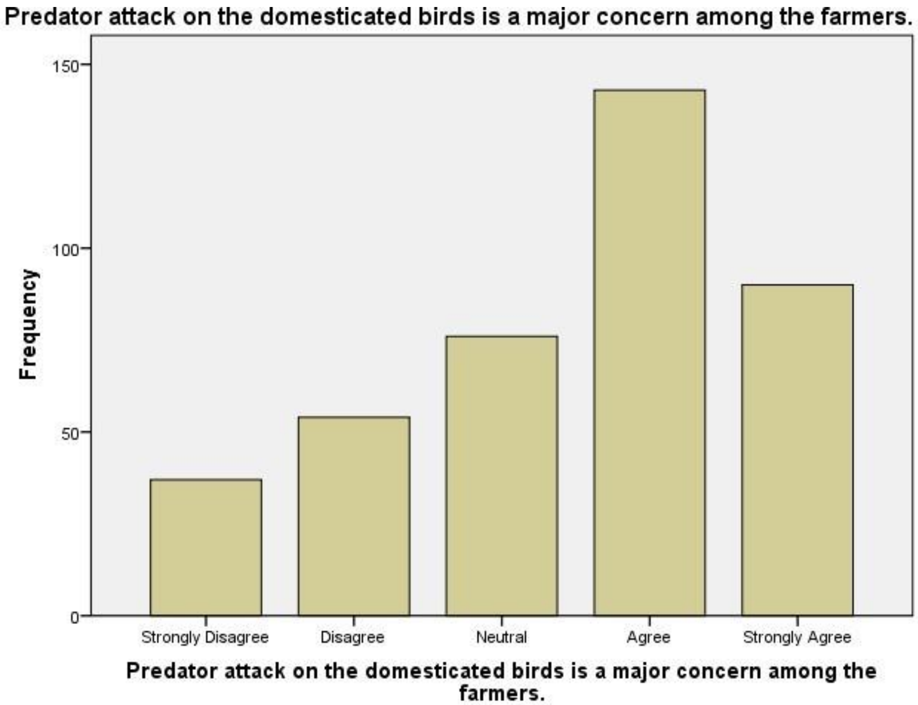

Figure 4.26: Predator attack on the domesticated birds

35.8% of the population opt for Agree as the response

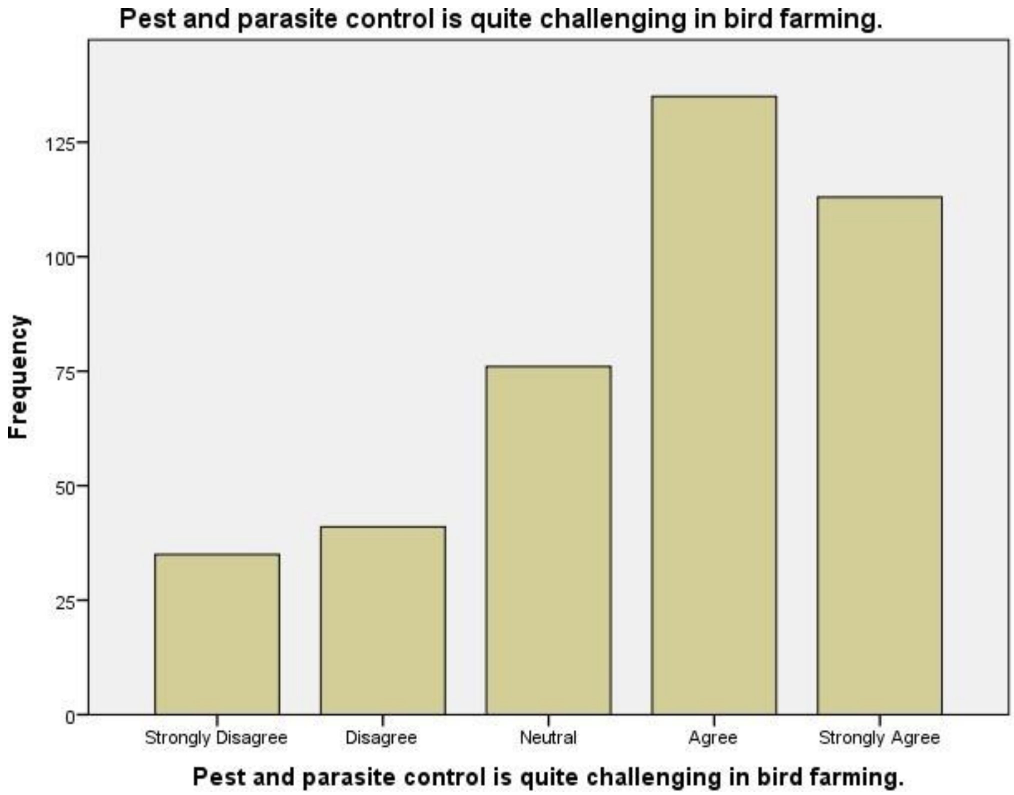

Figure 4.27: Pest and parasite control

33.8% of the population opt for Agree as the response

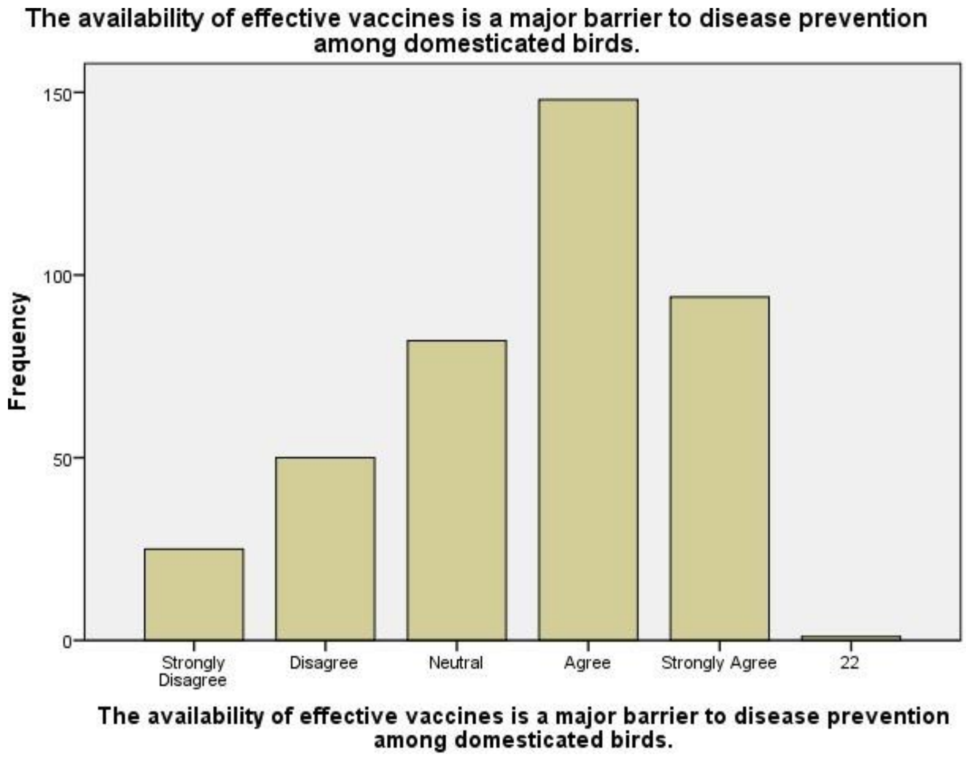

Figure 4.28: Availability of effective vaccines

37.0% of the population opt for Agree as the response

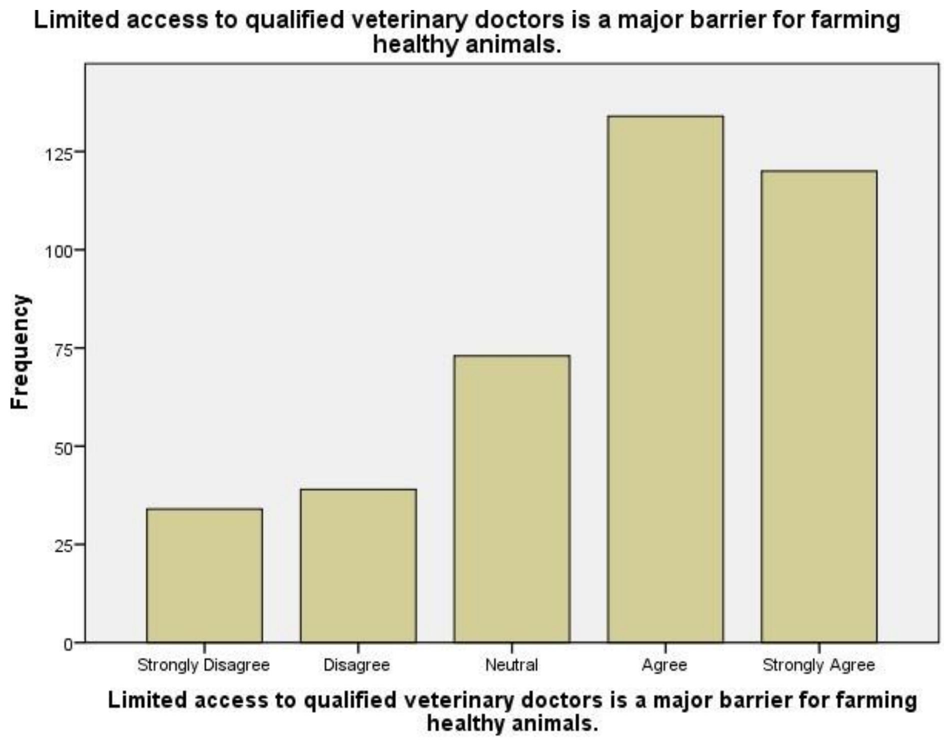

Figure 4.29: Limited access to qualified veterinary doctors

33.5% of the population opt for Agree as the response

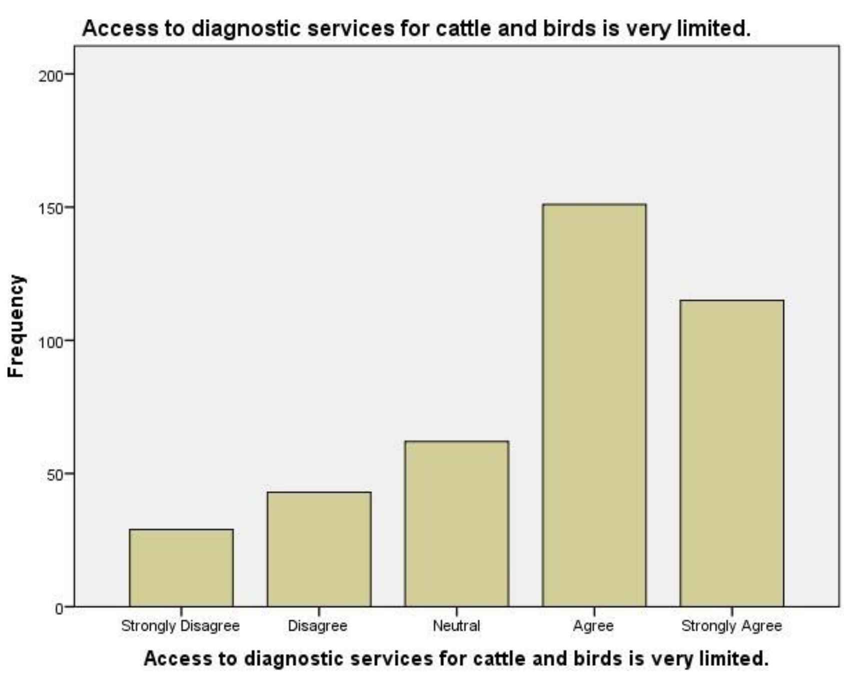

Figure 4.30: Access to diagnostic services for cattle and bird
37.8% of the population opt for Agree as the response

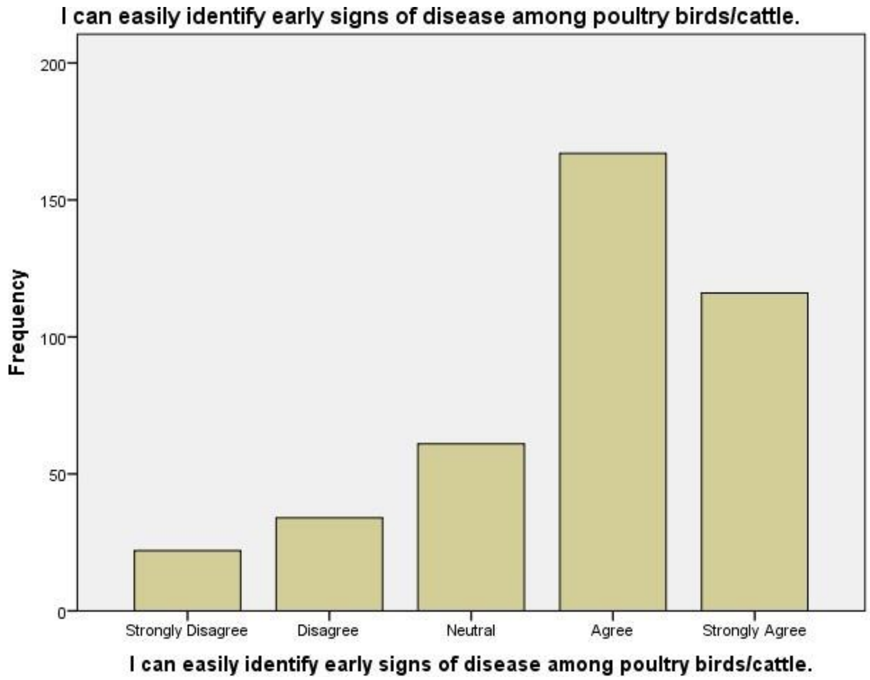

Figure 4.31: Early signs of disease among poultry birds/cattle
41.8% of the population opt for Agree as the response

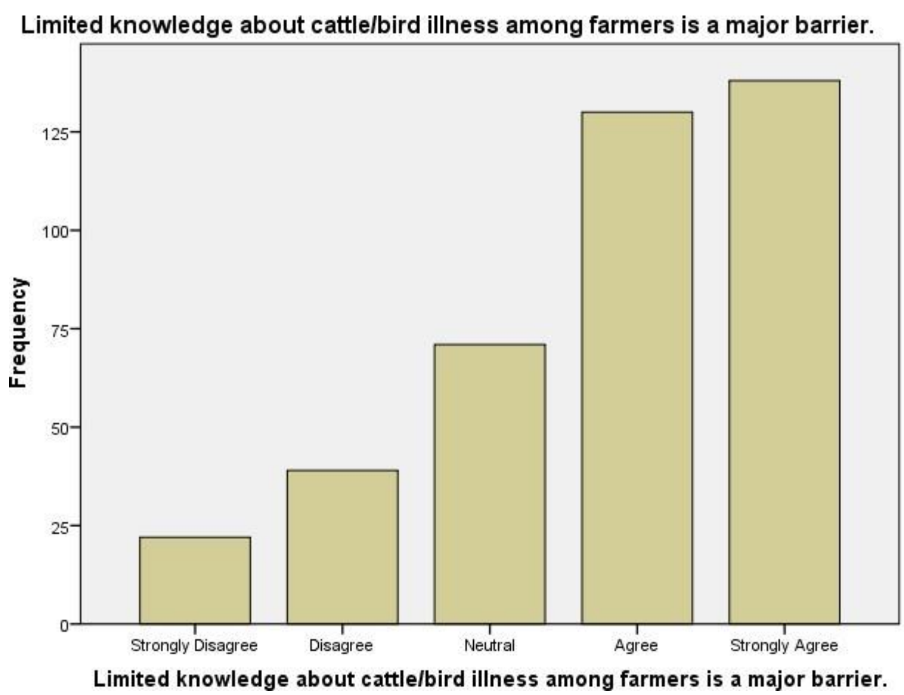

Figure 4.32: Limited knowledge about cattle/bird illness
34.5% of the population opt for Agree as the response

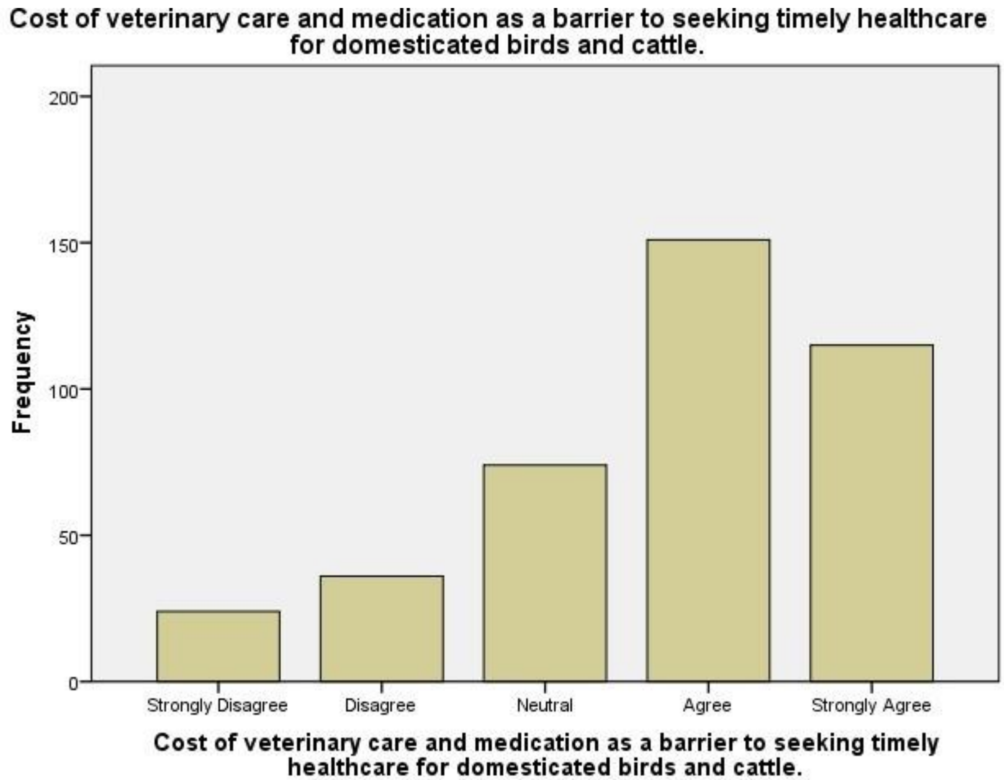

Figure 4.33: Cost of veterinary care and medication
37.8% of the population opt for Agree as the response

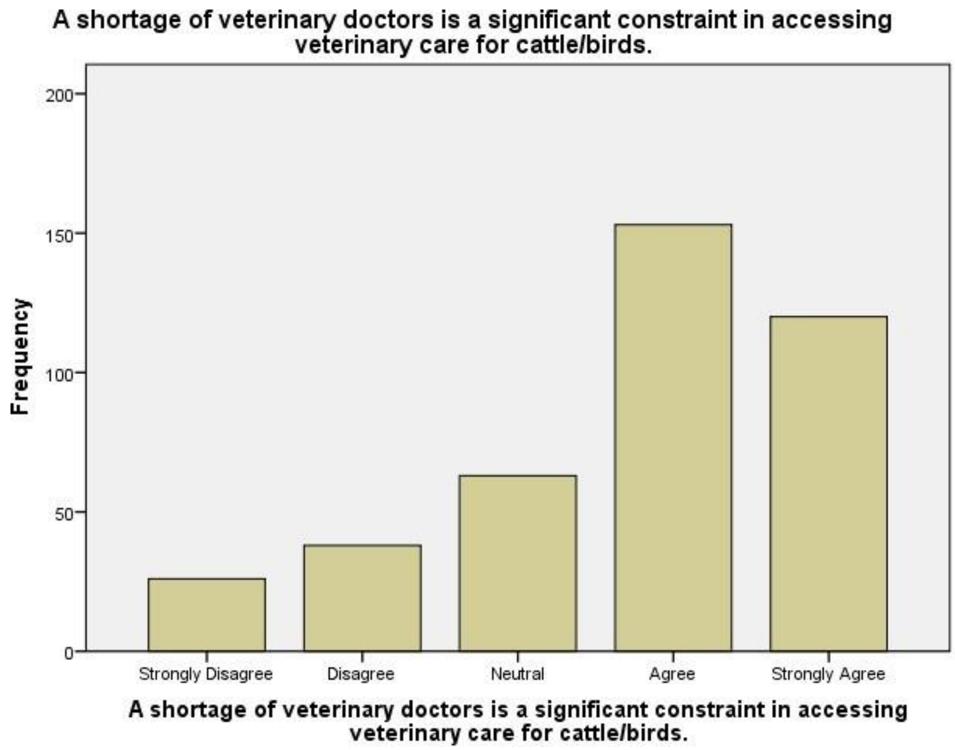

Figure 4.34: A shortage of veterinary doctors

38.3% of the population opt for Agree as the response

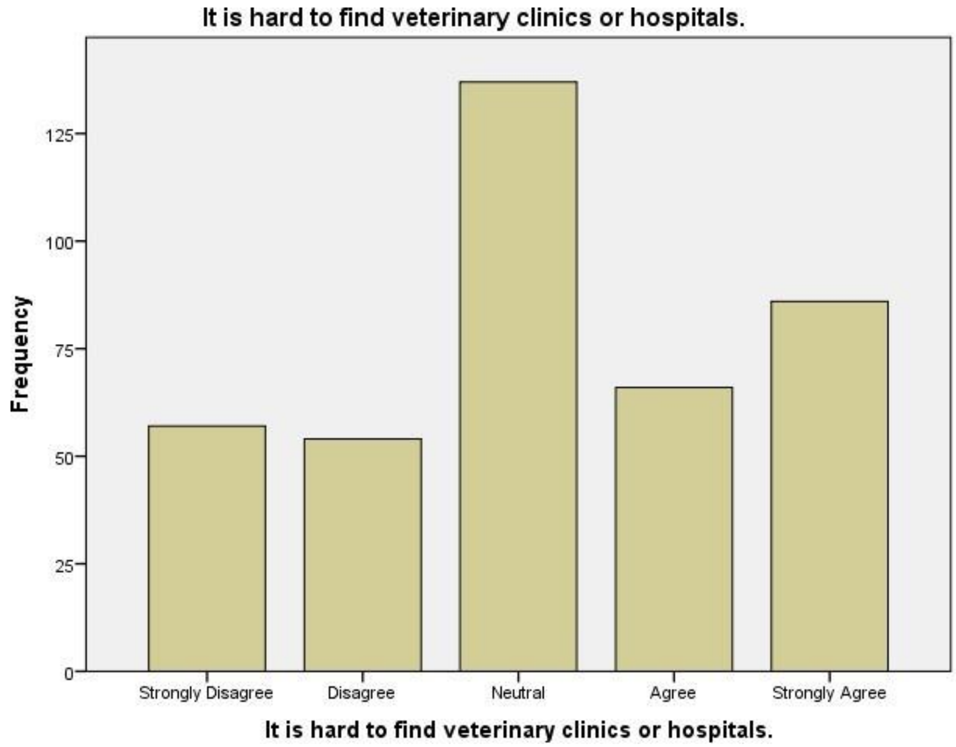

Figure 4.35: Veterinary clinics or hospitals
34.3% of the population opt for Neutral as the response

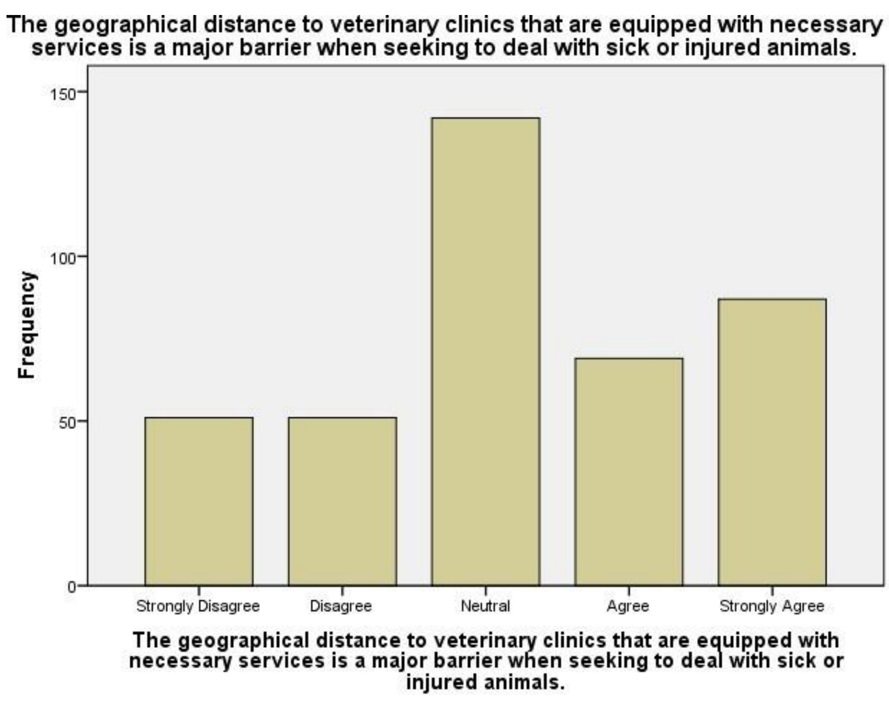

Figure 4.36: The geographical distance to veterinary clinics
35.5% of the population opt for Neutral as the response

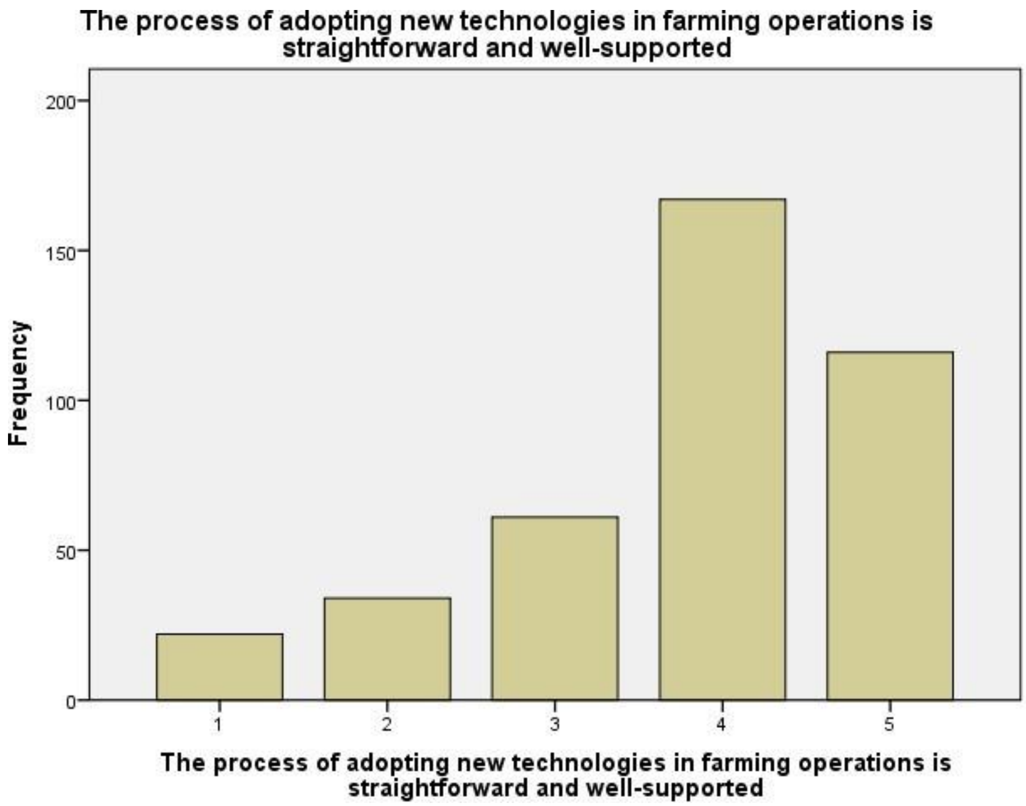

Figure 4.37: Process of adopting new technologies in farming operations

41.8% of the population opt for Agree as the response

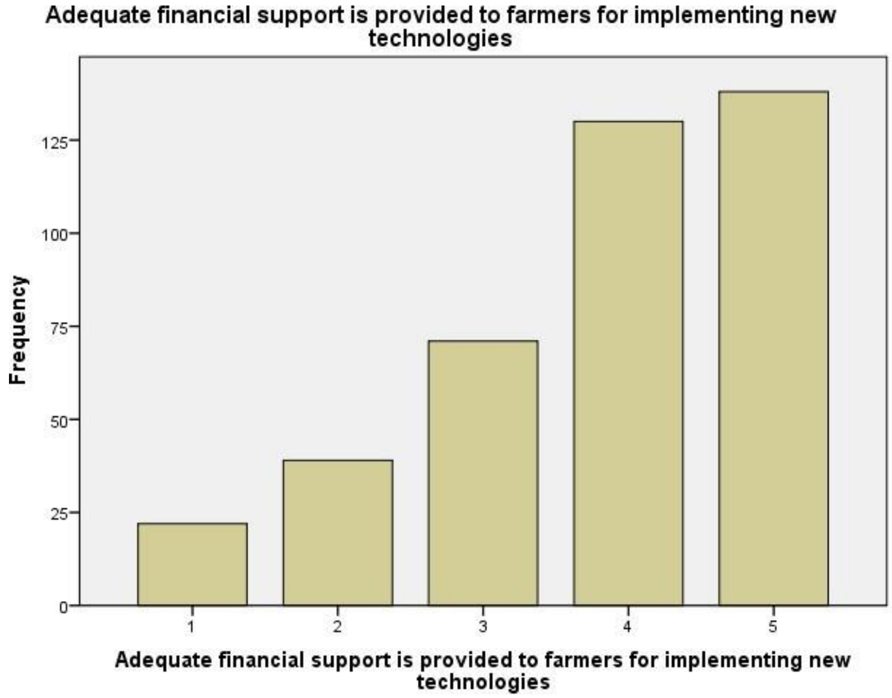

Figure 4.38: Adequate financial support

34.5% of the population opt for Strongly Agree as the response

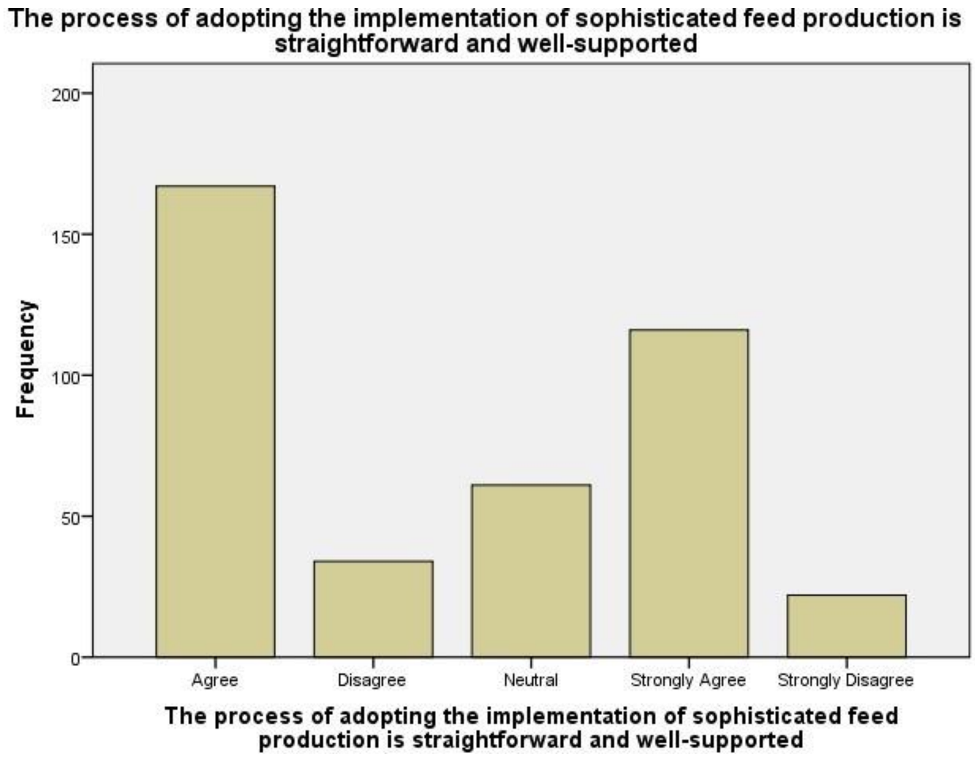

Figure 4.39: Proocess of adopting new technologies in farming operations

41.8% of the population opt for Agree as the response

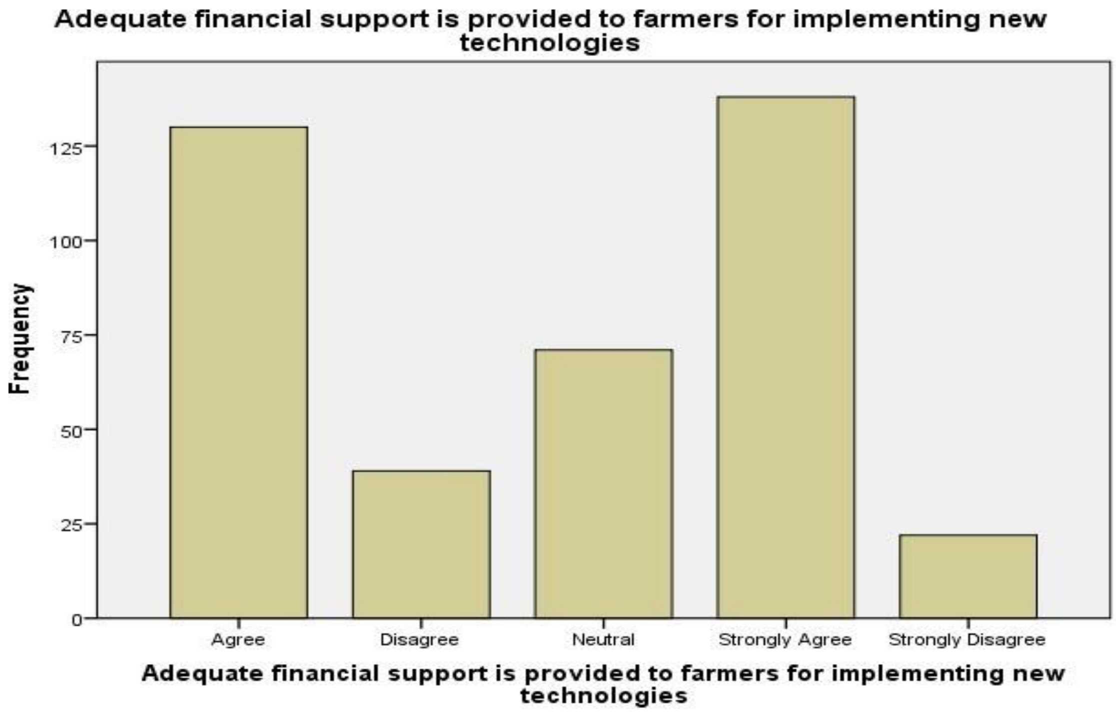

Figure 4.40: Adequate financial support

32.5% of the population opt for Agree as the response

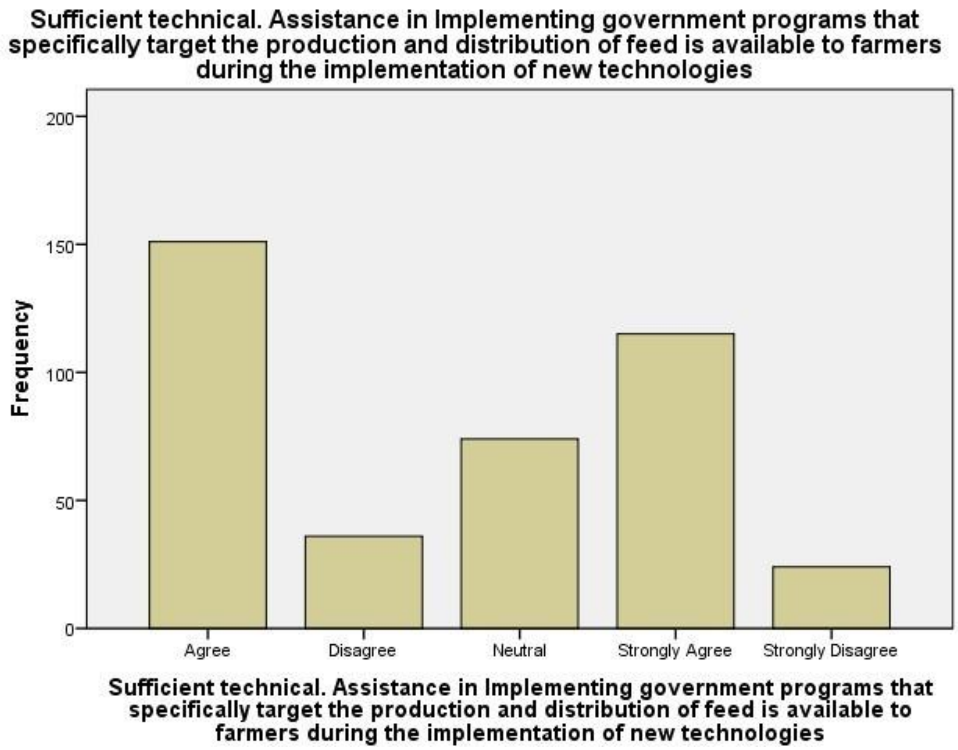

Figure 4.41: Sufficient technical assistance

37.8% of the population opt for Agree as the response