Analysis system dynamic of chicken egg production system: Case in West Sumatra Indonesia

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Abstract. A policy study is needed to guide the planning process to develop a sustainable agropolitan area for laying hens in Limapuluh Kota Regency. This research aims to design a policy for developing sustainable laying hen businesses through modeling the chicken egg production system. The dynamic systems approach was used to determine the production system for chicken egg production, which consists of two sub-systems: the layer chicken population sub-system and the business profit sub-system. Each sub-system interacts dynamically based on time. The research results reveal that the chicken egg production model in Limapuluh Kota Regency is accurate and can be used for decision-making activities. The model and its development can help determine the direction of chicken egg production policy to be developed into a sustainable agropolitan area. In the future, overall chicken egg production in Limapuluh Kota Regency is likely to increase, leading to an increase in profits for the egg-laying chicken farming business. However, an increase in feed prices without a corresponding increase in egg prices may hamper the rate of increase in egg.

1 Introduction

The purpose of producing agropolitans is for countries to encourage rural development, maximize the use of natural resources, raise farmer incomes, and boost regional economic growth. Growing laying hens is a popular and profitable business in many nations, including Indonesia. It is possible that they will help achieve the goals of sustainable development [1]. The Limapuluh Kota Regency (LKR) area has great potential in the subsector of laying hen farming [2]. Seeing this great potential, the development of agropolitan areas based on laying hens is one of the right choices as a balanced rural-urban development concept by adjusting the potential and characteristics of the area concerned. So that the backwash effect, both the drain of natural resources and rural human resources, can be avoided. According to[3], the development of agropolitan areas will encourage decentralization of development and authority in regions, villages, and cities that can strengthen each other, as well as the occurrence of economic development based on local resources through empowering local communities.

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Many complex problems are faced by the community in the development of agropolitan areas in the Limapuluh Kota Regency area, which are difficult to solve using only one specific method. One method that can be used to solve these complex problems is the system approach. [4], suggest that a systems approach can provide good problem-solving for complex multidisciplinary problems[5]. The systems approach is defined as a problem-solving methodology that begins with formulating goals and results as an operating system that can effectively be used to solve problems [6].

The development of agropolitan areas in the Limapuluh Kota Regency area faces several complex problems that cannot be solved with a single specific method. However, the system approach is one possible solution to these complex problems. According to [5], a systems approach can provide an effective problem-solving methodology for complex multidisciplinary problems. The systems approach involves formulating goals and results as an operating system that can be used to solve problems effectively [6]. To see the relationship between components in the development of agropolitan areas, it is necessary to build a model that is an implication of the system.

The agropolitan policy in Lima Puluah Kota Regency, West Sumatra, was initiated on June 6, 2005, when the Decree (SK) of the Regent of Fifty Cities Number 398 / BLK / 2005 was issued, designating Payakumbuh, Mungka, and Guguak Districts as agropolitan areas based on laying hen agribusiness. Initially, the laying hen industry showed promising economic development for laying hen farmers; however, in recent years, egg production has decreased and the number of farmers has also gradually decreased or even closed, which has a negative impact on the activities of residents who make a living from breeding laying hens. Sustainable development, as generally understood, is the ability to meet present needs without endangering the ability of future generations to meet their own, and agropolitan areas are typified by their capacity to maintain a balance between social, cultural, and political dynamics while guaranteeing the well-being of both present and future generations [7].

Overcoming these formidable obstacles, such as global climate change, resource depletion, and the need to meet the growing needs of the human population, requires concerted efforts, including the development of effective government policies and the adoption of more sustainable agricultural practice [8]. As the cumulative impacts of climate change become more evident across diverse sectors and regions, creative solutions are emerging and evolving to provide more comprehensive solutions [9]. A lot of developing countries favor regional development that ignores environmental safety concerns in favor of excessive resource exploitation (Surya).

The sustainability of laying hen farming in LKR produces unsatisfactory results in a number of dimensions. A number of factors are linked to the decline in production, with a connection to the implementation of government policies [10]. The agropolitan development of laying hen farms in LKR presents obstacles, including inadequate facilities, infrastructure, capital, and human resources [11]. The production levels are relatively low, insufficient to satisfy the demands of consumers from nearby regions like Riau, Jambi, Bengkulu, and Jakarta. Furthermore, the lack of infrastructure makes it difficult to market eggs and chickens because of the high cost of transportation to the surrounding areas [12].

A viable approach to improving the social and economic well-being of the community is the creation of agropolitan zones that include integrated laying hen farms. The goal of this research is to find a viable model for the growth of integrated laying hen farms in LKR in order to raise the community's standard of living. The purpose of this study is to develop a model for sustainable development of agropolitan areas based on integrated laying hen farms to improve the socio-economic living standards of the community. To achieve this goal, research activities in the second year consist of two stages, namely:

1. Analyze the regional system and build a model for the development of agropolitan laying birds in Lima Puluah Kota Regency, West Sumatra Province.
2. Formulate policy directions and strategy scenarios for the development of sustainable laying poultry agropolitan areas in Lima Puluh Kota Regency, West Sumatra Province

2 Research Method

2.1 Methods of Respondent Selection

Purposive sampling is a purposeful method of selecting respondents in order to obtain data and knowledge. It is customized to the surrounding conditions and the intended sample size, choosing respondents who are judged representative and have a thorough comprehension of the topics being studied. The respondents comprise experts and people from different agencies involved in the research topics who have a strong understanding of agropolitan problems.

2.2 Data Types and Sources

The data used for identifying agropolitan areas encompasses both primary and secondary sources. Primary data is gathered through questionnaires administered to selected respondents and experts, capturing information like total costs, farm revenues, and expert opinion scores. Secondary data is acquired from pertinent agencies in Fifty City Regency, including details on agricultural/livestock production, key commodities, population statistics, primary community activities in the agricultural/livestock sector, regional connectivity to neighboring areas, market proximity, adequacy of supporting facilities and infrastructure, the land potential for agropolitan development, GRDP, training, and extension education facilities, animal health services, security measures, and economic resources such as market availability and Village Unit Cooperatives (KUD). These secondary data sources are accessed through relevant agencies in Limapuluh Kota Districts such as Bappekab, and Central of Livestock and Agriculture.

2.3 Analysis Methods

The employed approach involves utilizing a dynamic system with the assistance of Powersim Constructor software version 2.5. The process in a dynamic system encompasses requirements analysis, problem formulation, model simulation, and model validation. The application of dynamic analysis in policy research facilitates a comprehensive understanding of policy evolution over time, intricate interactions among variables, dynamic system modeling, adaptation to environmental changes, trend identification, and long-term impact evaluation. This approach provides a more holistic foundation for designing and assessing effective and sustainable policies [13]. This research aims to examine policy changes and model new policies to enhance the agropolitan area in LKR in the future.[14]. There are five steps in creating a dynamic system model [15], as follows: (1) Issue formulation: in this phase, the problem to be solved is defined using a dynamic system model, and the associated variables are defined as well. (2) Dynamic Hypothesis: in this stage, a causal loop diagram is made to show the causal relationships between variables in the system. Once the causal loop diagram is made, it is changed into a simulation diagram or a flow diagram. Through simulations, dynamic hypotheses are produced by looking at the structural relationships between variables. (3) Formulation: in this phase, elements and variables in the system are converted into equations, levels, rates, and auxiliary variables. Estimates of initial values and parameter values are also made at this stage. Policy Formulation and Evaluation: The created model can be used as a reference for formulating or evaluating existing policies.
related to the modeled system. (4) Testing: This step is critical for comparing the output values generated by the simulation of the model with the output values from the real system. (5) Verification and validation of the model must be completed before performing this step. The next step is to create scenarios, simulate scenarios, and analyze scenarios. The scenario in creating a dynamic system model involves changing the values of specific variables to evaluate the results of the executed simulation. Scenario simulations are conducted to test several factors and variables that have been identified previously. Analysis and interpretation will identify which variables significantly influence productivity.

3 Result and discussion

3.1 Needs Analysis

Based on the literature review, several system actors who play a role in the egg production of layer chickens can be identified in Table 1.

<table>
<thead>
<tr>
<th>Actors</th>
<th>Their Needs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breeder</td>
<td>The amount of production and business profits increased</td>
</tr>
<tr>
<td>Government</td>
<td>Eggs and chicken meat are available and meet the needs of the community</td>
</tr>
<tr>
<td>Livestock Industry</td>
<td>Production continuity and large profit margins</td>
</tr>
<tr>
<td>Community</td>
<td>The needs of eggs and chicken meat are met</td>
</tr>
</tbody>
</table>

Based on Table 1, it can be seen that the needs of each system actor. System actors and their needs have been adjusted to the limits of research.

3.2 System modeling with dynamic systems analysis

The problem of chicken egg production in Limapuluh Kota Regency is a fairly complex system problem involving various components and variables that interact with each other. Chicken egg production is seen as a matter of system dynamics that change over time and are influenced by factors that are also dynamic. The chicken egg production system in Limapuluh Kota Regency is depicted on a cause-and-effect diagram and can be seen in Figure 1.

![Causal loop diagram of laying hen farming system in Limapuluh Kota Regency](image)

Fig. 1. Causal loop diagram of laying hen farming system in Limapuluh Kota Regency
Layer chicken population is a function of both the number of farmers and the environmental conditions in the farming area. The number of farmers is determined by the profitability of laying hen production and the business incentives offered by farmer-livestock cooperatives. Higher profits and more enticing business incentives will encourage more laying hen farmers to raise the population of layer chickens, which will increase egg production.

The profitability of the business depends on the ratio of revenues to costs; higher costs reduce profits. The majority of costs are incurred from the sale of animal feed, and the primary source of revenue is the sale of eggs. The amount of agricultural and livestock waste that is recycled into organic fertilizer and animal feed determines the environmental quality factors.

The conversion of refined waste into organic fertilizer offers a means of generating additional revenue for the business, whereas the conversion of agricultural waste into animal feed reduces the expenses linked to feeding animals. The dynamic system model that has been developed is limited to factors that are relevant to the production of chicken eggs, namely those that are impacted by variables pertaining to the number of layer chickens and business profits. The system for producing chicken eggs is divided into two main subsystems for modeling purposes: the subsystem of layer chicken population and the subsystem of business profits.

### 3.3 System Formulation

Model formulation is the formulation of a problem into a mathematical form that can represent a real system. Model formulation connects variables that have been identified in the conceptual model. Some of the assumptions used in modeling this study are:

#### 3.3.1 The total population of layer-breed chickens

The total population in 2016 was 95,743 per week according to BPS Kab. Limapuluh Kota's 2016 report. The production rate, a variable flow, depends on the availability of labor and the productivity of the labor force in rearing day-old chick (DOC) livestock from the rearing phase until they are ready for production (16 weeks). The population growth dynamics assumptions take into account inputs in the form of production variables and outputs in the form of depletion variables. The variable rate of depletion is dependent on the number of layer chickens that die during the rearing process and the number of layer chickens that are considered to have completed their production cycle. The variable efficiency of workers is assumed to be 1,500 heads per person per week, meaning that each worker can tend to 1,500 day-old chick (DOC) livestock each week. The number of layer chickens killed in rearing is assumed to be 5% of the livestock population and the number of livestock estimated is assumed to be 37% of the population per week. The amount of value and assumption of the value used from each variable is sourced from statistical data from the Central Bureau of Statistics of Limapuluh Kota Regency in the 2016-2021 time frame.

#### 3.3.2 Assumption of feed consumed by livestock

Since the feed mill supplies the concentrate feed, it is assumed that the feed consumed by livestock is a combination of concentrate feed (45% of the total feed requirement), rice bran (15% of the total feed requirement), and corn (40% of the total feed requirement). The feed for rice bran and corn is obtained from the agricultural yield of these crops in Limapuluh Kota Regency. The variable denoting the percentage of rice bran and corn harvest is assigned a value equal to the average value obtained from the rice and corn crops in Limapuluh Kota.
Regency from 2016 to 2021. The livestock waste in this model is assumed to be used only as manure, with an assumed weekly value of 0.231 kg per head.

### 3.3.3 Variable demand for chicken culled

The market demand for chicken meat is represented by the demand for culled chickens and the value of this variable is influenced by the interaction between the variables "culled" and "time change demand." The value of the chicken demand variable affects the number of day-old chicks (DOC) needed, and the number of DOC that can be prepared for production as layer breed chickens are determined by the labor force availability and worker competency.

### 3.3.4 Business Revenue Variables

Assuming a productivity rate of 7.7 kg per head per week and an egg price of Rp 23,700 per kg, the egg acceptance variable in the model represents the sales value of eggs from purebred layer chickens; the values for laying hen productivity and egg prices are derived from the average values observed between 2016 and 2020; and the culled revenue variable represents the sales value of chicken meat from laying hens.

### 3.3.5 Variable total cost of business

The total cost variable of the business consists of the sum of the feed, other expenses, and operating costs. The variable feed costs are determined by the variable egg production, which is valued at Rp. 10,000 per kilogram of eggs, based on a Feed Conversion Ratio (FCR) of 2.30. The cost of animal feed for laying hens is expected to increase by 30% annually due to the yearly trend of the price of concentrate feed rising. The operational cost variables are those that pertain to the general running of the business. All of the costs that farmers incur during the production process are included in the operating cost variables. These costs include electricity, water, labor wages, maintenance, materials, social costs, health, security, fuel, and more. The value of the operational cost variables in the model is Rp. 1,000 per kilogram of eggs. The total cost of all of the expenses that farmers incur is included in the other cost variable. This includes sales, vaccines, medicines, miscellaneous costs, and depreciation on pullets. The value of the other variable costs in the model is Rp. 2,570 per kilogram of eggs.

### 3.3.6 Business profit variable

It is assumed that profits from livestock business operations will be allocated for credit installment payments and will also contribute to the overall profits of livestock cooperatives. The business profit variable is derived by deducting the total operating costs from the business revenue variables.

### 3.3.7 Labor variables

Labor variables are stock variables that are shaped by both inflows and outflows. Inflows are influenced by expected labor force variables and the amount of time needed for worker adjustments. The worker adjustment time variable is assumed to be 8 weeks, which represents the average amount of time workers must wait before beginning work in the cage. Outflows are influenced by the variable that represents the average amount of time workers stay in their
positions, which is assumed to be 104 weeks, which indicates the average amount of time a worker stays in their position before quitting.

### 3.3.8 Labor productivity

Given that the weekly labor output is considered to be 1,500 heads per person, each worker can take care of 1,500 chickens in total.

### 3.3.9 Farmer variables

The term "farmer variables" refers to those who own laying hens in addition to workers; the number of farmers is assumed to be 25% of the total number of workers because farmers manage their livestock business in addition to acting as workers.

### 3.3.10 Livestock cooperatives

In the model, it is assumed that all laying hen farmers are members of Livestock cooperatives. Members of livestock cooperatives give 5% of business profits for the development of livestock cooperative businesses directly whenever farmers make profits.

### 3.3.11 All farmers

All farmers who raise laying hens are required to pay the financial institution on credit. It is anticipated that credit installment payments amount to twenty percent of business profits, provided that all farmers comply with timely payments in order to avoid any negative credit issues with financial institutions.

### 3.4 System modeling

Attempting to replicate the system is the goal of the modeling stage. It is a creative process that is not strictly linear but rather must follow scientific principles and logical-iterative thinking. The steps in the modeling procedure include redefining the problem to be addressed in accordance with the goals of the system study, formulating hypotheses, creating models, testing and analyzing those models, and so on. According to[16], successful modeling depends on establishing a relationship between the virtual world represented in the model and the real world, so as to guarantee that the model fulfills its function of simplifying the system. Figure 2 shows the model of the laying hen farming system in Limapuluh Kota Regency.
3.5 Model Validation

According to [17] and [18], validation is the process of determining whether a conceptual model accurately reflects a real system. This involves determining whether the simulated conceptual model accurately represents the real system being represented. As a system simplification, the model necessitates that the model maker convince the model user that the built model is appropriate for solving the current problem, an essential step in enabling well-informed decision-making. The model's testing phase is divided into two components, according to [19] the structural validation test and the performance validation test. The purpose of the structural validation test is to determine the degree to which the model's structural similarity to the real structure matches. It is divided into two parts: construction validation and structure stability. Performance validation tests are carried out to provide assurance regarding the degree to which the model's performance matches the system's actual performance. This is necessary in order to determine whether the behavior of the model's output is consistent with the observed behavior in empirical data, thereby guaranteeing that the model conforms to factual representation. The degree of disagreement between the model's output and empirical data can be measured by evaluating its absolute mean deviation (AME = absolute mean error). It has been suggested by [20] that the acceptable deviation range is between 5 and 10%.

The formula for computing the value of AME is as follows:

\[ \text{AME} = \frac{(Si - He)}{He} \times 100\% \]

Where \( Si = \frac{\Sigma Si}{N} \) and \( He = \frac{\Sigma He}{N} \)

The explanation is as follows: \( S \) stands for the simulation value, \( A \) for the real value, and \( N \) for the observation time.
AME analysis results show that the model for the laying hen farming system in Limapuluh Kota Regency performs admirably, displaying precision and meeting scientific standards. The AME test was used in this study's performance validation, using actual data pertaining to the population of laying hens (head/week) and egg production (kg/week) in Limapuluh Kota Regency.

**Table 2. Comparison of layer laying hen population data and actual egg production with simulated model results of laying hen farms in Limapuluh Kota Regency**

<table>
<thead>
<tr>
<th>Year</th>
<th>Actual Population of Layer (tail/week)</th>
<th>Actual Egg production (kg/week)</th>
<th>Simulation Population of Layer (tail/week)</th>
<th>Simulation Egg production (kg/week)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>95.742</td>
<td>735.072</td>
<td>95.743</td>
<td>737.221</td>
</tr>
<tr>
<td>2017</td>
<td>122.104</td>
<td>939.049</td>
<td>113.849</td>
<td>876.642</td>
</tr>
<tr>
<td>2018</td>
<td>143.278</td>
<td>1102.300</td>
<td>130.513</td>
<td>1004.957</td>
</tr>
<tr>
<td>2019</td>
<td>143.740</td>
<td>1104.201</td>
<td>149.617</td>
<td>1152.055</td>
</tr>
<tr>
<td>2020</td>
<td>149.011</td>
<td>1148.878</td>
<td>171.517</td>
<td>1320.683</td>
</tr>
<tr>
<td>Average</td>
<td>130.775</td>
<td>1005.900</td>
<td>132.248</td>
<td>1018.312</td>
</tr>
<tr>
<td>AME</td>
<td>1.13 %</td>
<td>1.23%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2 shows the results of the model output and performance validation. The AME value is below 5 percent, ranging between 1.13 and 1.23 percent. The results of the AME analysis show that the model of the laying hen farming system in Limapuluh Kota Regency has good performance, is relatively precise, and is scientifically acceptable.

### 3.6 Scenario of Sustainable Development of Laying Hens Farm System in Limapuluh Kota Regency

After taking sustainability and model performance into account, the analysis of system performance shows that the current system is positioned as reasonably sustainable. Time dynamics will introduce changes in system performance in the future. The application of scenario formulation for system development can help maximize the benefits of the laying hen farming system and improve system performance for sustainability. Seven significant factors influencing the interconnected system have been identified after an analysis of their interactions, and these factors are further explained and described as possible future changes or evolutions. Table 3 shows the prospective key factors for the development of laying hen farming systems in Limapuluh Kota District.

**Table 3. Prospective key factors for the development of sustainable laying hen farming systems in Limapuluh Kota District**

<table>
<thead>
<tr>
<th>No</th>
<th>Factors</th>
<th>(state)</th>
<th>1A</th>
<th>1B</th>
<th>1C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Utilization of livestock waste</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Environmental carrying capacity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Egg Price</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Farmer Revenue</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Workforce</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Cooperative advantages</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Credit disbursement</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Based on Table 3, several scenarios are formulated by pairing the anticipated changes and analyzing their implications on the system, based on the condition (state) of each factor. Three development scenarios are formulated for the development of a sustainable commercial layer chicken farming system in the Limapuluh Kota Regency: (1) conservative-pessimistic scenario, (2) moderate-optimistic scenario, and (3) progressive-optimistic scenario. There may be more development scenarios, but these three are the most likely to occur in the future based on the current state of each key factor. The profitability of layer farming and the commercial incentives provided by farmer-livestock cooperatives have an impact on the number of farmers [21]

The following variables in the model represent these key factors: (1) the manure fertilizer variable, which represents the key factor of livestock waste utilization; (2) the purebred chicken population, feed requirements, corn requirements, corn stock, requirements for rice bran, and rice bran stock, which represents the key factor of feed carrying capacity; (3) the egg production, egg receipts, and egg prices, which represents the key factor of egg price improvement; and so on. The key factors that represent farmer income are represented by the following variables: (4) business revenue, total business costs, and business profits; (5) labor; the key factor that represents labor absorption; (6) cooperative profit; the key factor that represents the availability of agribusiness infrastructure; and (7) business profit and credit installment payment variables.

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