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Dynamic Modeling of Catfish Farming Development Using iThink Software

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Abstract

This study analyzes the development of catfish farming in the Special Region of Yogyakarta (DIY) using a dynamic systems approach with iThink software. The model evaluates the relationships between local production, demand, external supply, and market prices over a 10-year period. The results indicate that local production can only partially meet demand, leading to a high dependency on external supply, primarily from Boyolali Regency and East Java. Simulations identify optimal strategies to enhance production efficiency, maximize land utilization, and reduce reliance on external supply. Model validation demonstrates that the simulation results align with historical data, making it a reliable tool for supporting sustainable strategic policy planning. This study is expected to provide solutions for food security and strengthen the self-sufficiency of the fisheries sector in DIY.

Keywords: Catfish farming, dynamic system, local production, external supply, iThink.

1. Introduction

The development of the marine and fisheries sector, particularly in the Special Region of Yogyakarta (DIY), is directed towards creating integration among subsystems in fisheries activities. This includes seed production, fish farming for consumption, post-harvest management, and product diversification. Additionally, this sector prioritizes the provision of alternative feed, strengthening business institutions, improving human resource quality, and expanding marketing networks (Iles & Marsh, 2012). However, the sector still faces various challenges, such as traditional business management, low local production meeting only 30% of daily consumption needs and a high dependency on external supply (Asif & Muneer, 2007).

The demand for catfish in DIY is estimated to reach 12–16 tons per day, while local production can only supply 4.2 tons per day. This shortfall is met through external supply, primarily from Boyolali Regency (60%) and East Java (10%) (Suryanto et al., 2020). This dependency highlights the need for strategies to increase the contribution of local production in fulfilling the consumption needs of Yogyakarta's population. These efforts include enhancing efficiency in production, distribution, and marketing. Integrated logistics and supply chain models have proven to be effective solutions in addressing challenges in the fisheries sector, as demonstrated by the improved supply chain management performance of fresh tuna at PPS Nizam Zachman Jakarta through coordinated business actor collaboration and efficient technology application (Pailin & Romli, 2025). In this context, a dynamic systems approach provides a comprehensive method for understanding the interactions among factors influencing the aquaculture system holistically. Previous research has utilized dynamic system simulations to analyze catfish farming development, focusing on the relationship between demand, production, and policies that support increased productivity and sustainability in this sector (Susanto & Othmana, 2021).

By employing dynamic system simulations, the potential for local production development can be analyzed in greater depth, including the design of relevant policies to enhance productivity and sustainability in this sector. This study aims to formulate policy recommendations for the development of catfish farming in DIY using a dynamic systems approach. The primary focus of this research is to analyze the relationships among demand, production, and external supply while identifying optimal strategies to enhance local production. Therefore, this study is expected to provide policy recommendations that support the sustainability and self-sufficiency of the aquaculture sector in DIY.

2. Literature Review

2.1. Dynamic Systems

The dynamic systems approach has proven to be an effective method for analyzing complex interactions within aquaculture systems. Recent studies indicate that this approach can be used to understand fluctuations in production, demand, and supply, as well as their impact on the sustainability of the fisheries sector (Susanto & Othmana, 2021). Through dynamic system simulations, the interactions between factors such as productivity, market prices, and consumption can be holistically analyzed to generate optimal policies. This approach is becoming increasingly relevant in aquaculture, as dynamic systems enable more adaptive management in response to ecological and economic changes (Troell et al., 2014). The dynamic systems approach is one of the methods used to address challenges in aquaculture systems. The modeling process using dynamic systems involves the following steps:

2.2. Behavior Identification

This step involves identifying and mapping problems based on field data. Problem mapping includes determining the variables within the fisheries industry system and testing whether significant relationships exist between these variables. The identification of system variables is conducted in collaboration with officials responsible for the fisheries industry in the study area. Additionally, a mental model in the form of a Causal Loop Diagram (CLD) is developed at this stage.

2.3. Computer Model Development

The fisheries industry system model (commonly referred to as the Stock Flow Diagram (SFD)) is developed based on the mental model created in collaboration with the Marine and Fisheries Agency. Data input into the computer model is carried out using iThink software. Once the data is entered, the model is simulated, producing graphical outputs that illustrate the values of each variable after execution.

2.4. Model Validation

Model validation is necessary to ensure that the model and its outputs do not deviate from real-world conditions. This is conducted by comparing real system data, represented by statistical data graphs, with the simulation results generated by the model.

2.5. Sensitivity Analysis

Sensitivity analysis is performed to identify key factors that significantly influence the system, commonly referred to as leverage points (Doughlas-Smith et al., 2020). Leverage points are variables that, with small changes, can have a substantial impact on the entire system. Identifying leverage points is crucial for developing policy scenarios, as simulations on these variables are used to determine the most optimal policies (Boutilier et al., 1999). Problems that can be effectively modeled using the dynamic systems methodology are those that exhibit dynamic characteristics (changing over time) and involve feedback structures, such as fisheries resource management and supply distribution (Morecroft, 2015).

2.6. Definition of Catfish

Catfish belong to a family of freshwater fish that are easily recognizable by their smooth, slightly flattened elongated bodies and two long whisker-like barbels extending from their mouths. Catfish are widely consumed due to their desirable taste and are commonly prepared by frying or grilling.

2.7. Catfish Farming

Catfish farming is an activity in which individuals cultivate catfish for commercial purposes. Catfish are relatively easy to farm in warm water environments, providing an affordable source of food for local markets. They can be cultivated in concrete ponds, earthen ponds, tarpaulin ponds, tanks, and small rivers.

Catfish farming is highly favored by farmers due to its expanding market. Local fish farming should be prioritized when the goal is to increase food production and improve community nutrition. Therefore, information on the general biology of the local fish species to be farmed is a fundamental requirement in the planning process.

2.8. iThink / Stella Software

STELLA (short for Systems Thinking, Experimental Learning Laboratory with Animation), also marketed as iThink, is a visual programming language for system dynamics modeling introduced by Barry Richmond in 1985. This software, distributed by isee systems (formerly High Performance Systems), allows users to create models as graphical representations of a system using four fundamental building blocks. STELLA has been widely used in academia as a teaching tool and has been applied in various research studies and business applications. The software has received positive reviews, particularly for its ease of use.

3. Materials and Methods

This research was conducted in the Special Region of Yogyakarta (DIY), covering five regencies and cities (Yogyakarta, Bantul, Sleman, Gunung Kidul, and Kulon Progo). Data collection involved sampling fishery business actors across these five regions. The research was designed and developed following the methodology illustrated in Figure 1.

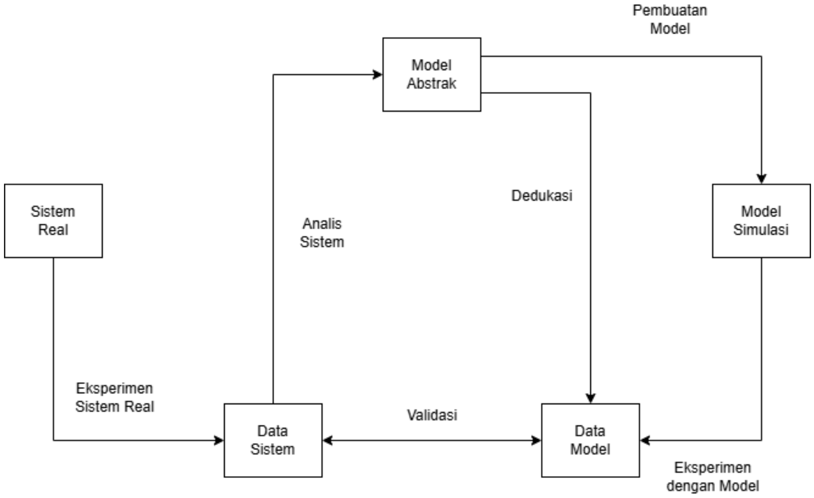

Figure 1: Research Stages

3.1. Real System

The study began with observations and data collection related to the real-world management of catfish aquaculture, particularly focusing on dynamic factors influencing productivity. Key factors analyzed included catfish growth rates, pond capacity, feed utilization, and identifying issues such as overpopulation or feed efficiency. The model was developed using iThink software to simulate various development scenarios and optimize aquaculture outcomes.

3.2. System Data

The collected system data was processed to determine parameters for dynamic simulation, including regional production in DIY, population size, per capita consumption, regional demand, the gap between demand and production, pricing, and external supply. These parameters were used to estimate local catfish production in DIY.

3.3. Abstract Model

The abstract model of this research illustrates the dynamic relationship between DIY catfish production, regional demand, external supply, and market price to maintain market equilibrium. If demand increases due to higher fish consumption, local production will be pressured, and external supply will serve as a temporary solution to meet the shortfall. Conversely, if production meets or exceeds demand, market prices will stabilize or decrease depending on the system’s sensitivity to equilibrium.

3.4. Dynamic Simulation Model

The dynamic simulation model in this research depicts the interrelationship between key variables in the DIY catfish farming system, including local production, DIY demand, external supply, and market prices, using the Stock and Flow approach. The model predicts stock changes, such as production accumulation, supply levels, and revenue flow, based on regional production, consumption rates, and external supply influx.

The system dynamics involve market balance, which is affected by the gap between demand and production, determining the need for external supply and influencing price fluctuations. The simulation results provide insights into production trends, supply requirements, and price variations over a 10-year period, enabling the development of strategic policies to enhance productivity and market stability in the DIY catfish sector.

3.5. Model Data

The data used in this simulation model consists of key variables such as local catfish production, DIY demand, external supply, and market prices, interconnected through dynamic equations. Production data was obtained from all regencies in DIY based on historical records, while demand was calculated based on population size and per capita consumption. External supply was estimated from contributions by Boyolali and East Java, and market price was influenced by the balance between demand and production. The model integrates these datasets to predict demand fluctuations, production capacity, supply levels, and price trends over a specific period, assisting in market pattern analysis and policy formulation.

3.6. Validation

The validation of the dynamic simulation model was performed by comparing the model's output graphs (demand, production, and price trends) with real historical data and statistical records. This process ensures that the model accurately represents the real-world system. If there are significant discrepancies between the simulation results and actual data, adjustments are made by calibrating parameters or modifying the system structure. The validation process aims to ensure that simulation results can be used as a reliable basis for policy analysis and decision-making.

4. Results and Discussion

4.1. Identification of Key Issues

This study identifies several key issues, particularly in terms of stock, flows, and auxiliary variables. Below is an explanation of each attribute:

4.1.1. Stocks

- Production Accumulation: Aggregates catfish production from all regencies in DIY.
- Supply Accumulation: Collects catfish supplies from external regions to meet demand.
- Revenue Accumulation: Calculates total income based on production and market prices.

4.1.2. Flows

- DIY Catfish Production: The production flow from all regencies (Bantul, Sleman, Gunung Kidul, Kulon Progo, and Yogyakarta City)
- External Supply: The supply flow from other regions such as Boyolali and East Java.
- DIY Demand: The consumption flow based on population size and per capita consumption.

4.1.3. Auxiliary Variables

- Market Price: Determined by the balance between demand and production.
- Population: Changes based on birth and death rates.
- Demand and Production Gap: Determines whether external supply is needed.

4.2. Black-Box Diagram

The black-box diagram in Figure 2 illustrates the Smart Community Model, where input, environmental factors, and output interact with each other. Uncontrolled Inputs include population changes, consumption trends, price fluctuations, and external supply, which are external factors that are difficult to regulate. Controlled Inputs include government policies, seed and feed provision, and land optimization, which can be managed to enhance system performance. Environmental Factors, such as geographical conditions and local culture, influence the overall system dynamics. Desired Outputs include increased production, supply chain efficiency, market balance, and higher farmer income. Undesirable Outputs, such as dependency on external supply, technological disparity, and price fluctuations, need to be anticipated to achieve system objectives.

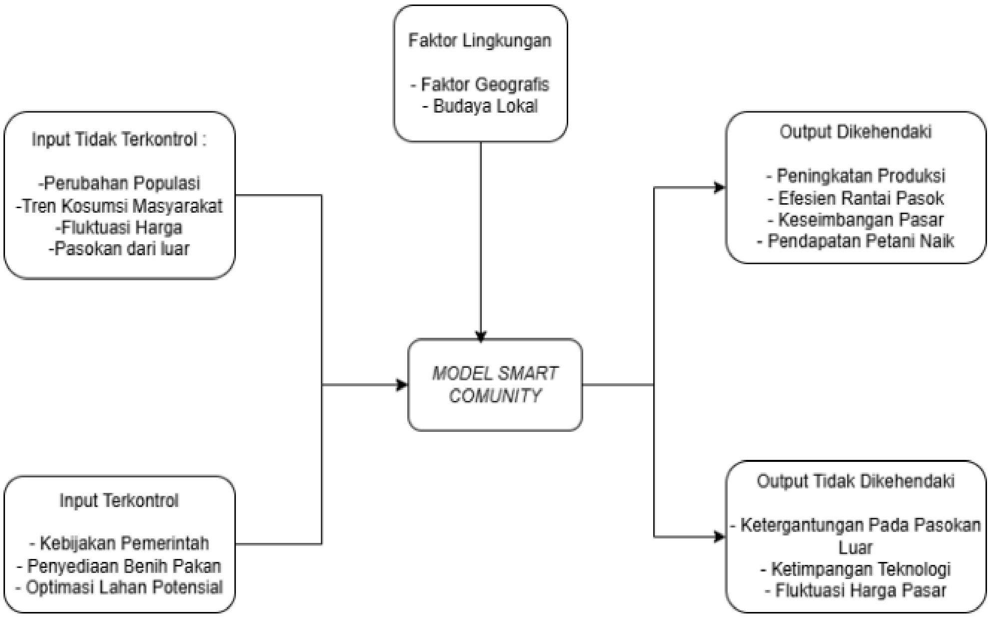

Figure 2: Black-Box Diagram

4.3. Causal Loop Diagram (CLD)

The Causal Loop Diagram (CLD) in Figure 3 illustrates the dynamic relationships between various variables in the catfish supply and demand system. The diagram consists of multiple feedback loops that depict how one variable influences another directly or indirectly.

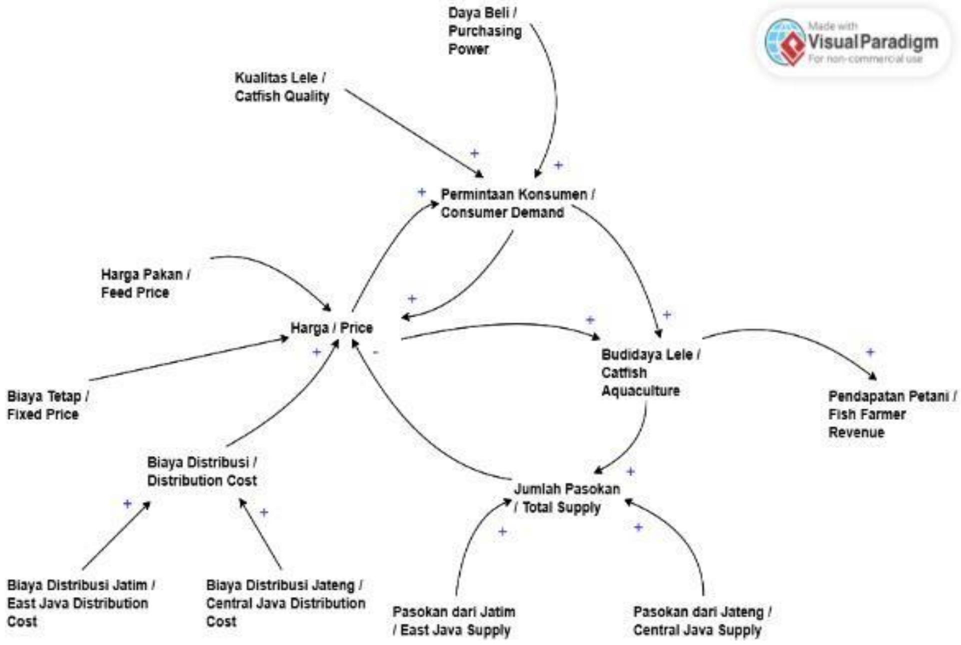

Figure 3: Causal Loop Diagram

Key elements of the CLD include:

- Feed Price (+): If feed prices rise, catfish prices will also increase.
- Catfish Quality (+): Higher quality catfish increase prices due to added product value.
- Distribution Cost (+): Comprising fixed and regional distribution costs (Central Java and East Java). If these costs rise, catfish prices also increase.

- Consumer Demand (+): Influenced by purchasing power. Higher purchasing power increases demand.
- Price (-): If catfish prices rise, consumer demand tends to decrease.
- Total Supply (+): Higher prices incentivize farmers to increase production.
- Fish Farmer Revenue (+): Increased revenue encourages more catfish farming.
- Catfish Aquaculture (+): Influenced by local production and external supply (Central Java and East Java). If external supply increases, total supply also rises.

4.4. Stock and Flow Diagram Model

The dynamic modeling approach in the Stock and Flow system aims to develop catfish aquaculture policies by analyzing the cause-and-effect relationships between subsystems. This model utilizes causal loops to illustrate stock flow and the interactions among key variables affecting catfish aquaculture in DIY.

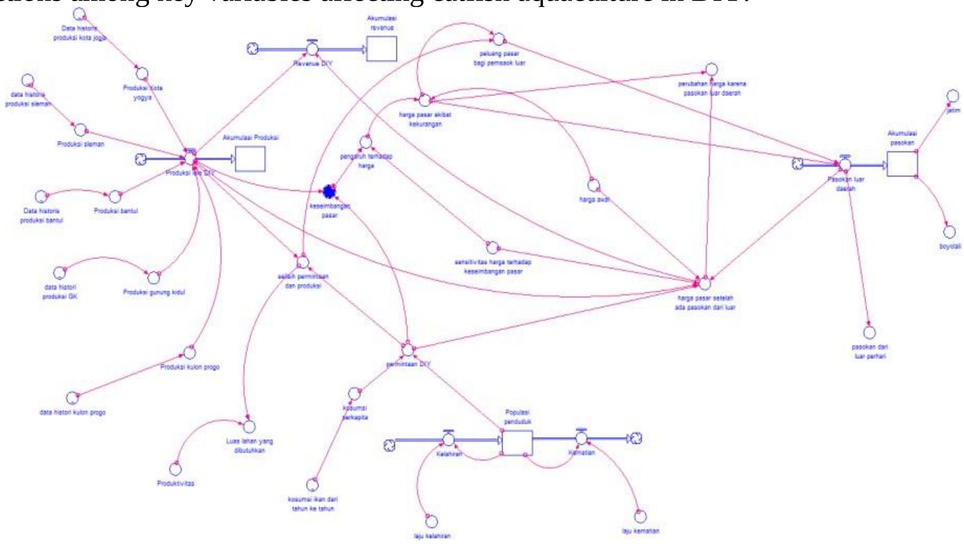

Figure 4: iThink Model

Stock Components

- DIY Catfish Production: Accumulated production from all regencies in DIY (Bantul, Sleman, Gunung Kidul, Kulon Progo, Yogyakarta City).
- External Supply: Accumulated supply from external regions (Boyolali and East Java) to compensate for demand shortages.
- Revenue: Accumulated income from production sales based on market prices.
- Population: Determines DIY demand trends based on birth and death rates.

Flow Components

- Regional Production: Inflow to production stock based on productivity per region and land area.
- DIY Demand: Consumption demand flow affected by population growth and per capita consumption.
- External Supply: Inflow to DIY when local production is insufficient.
- Farmer Income: Inflow of revenue based on market prices and total catfish sales.

Auxiliary Variables

- Market Price: Determined by the balance between demand and production/supply.
- Demand and Production Gap: Determines the need for external supply.
- Productivity: Influenced by external factors such as government policies, seed availability, and feed quality.
- Required Land Area: Determined by productivity and demand gap.

4.5. DIY Population Growth

Population data in Figure 5 shows a consistent increase from 4,155,313 people in 2023 to 4,793,438 people in 2032, with an average annual growth rate of 1.5%–2%. This growth directly contributes to rising catfish demand, making it a critical factor in planning local production and managing supply to sustainably meet growing needs.

Table 1: DIY Population Growth Trends

Years	Population
Initial	4,089,875.00
0	4,155,313.00
1	4,221,798.01
2	4,289.346,78
3	4,357,976.32
4	4,427,703.95
5	4,498,547.21
6	4,570,523.96
7	4,643,652.35
8	4,717,950.79
9	4,793,438.00

4.6. Regional Catfish Production Data in DIY

Data from BPS (Badan Pusat Statistik) for the 2018–2022 period in Figure 6 shows fluctuating catfish production trends in DIY. Initial production growth reflects intensification efforts and agricultural policy implementation. However, in later years, growth slowed due to land limitations, declining productivity, or external factors such as weather changes and market distribution issues. This data serves as an important basis for analyzing production trends and formulating strategic policies to enhance production capacity and support local food security.

Table 2: DIY Regional Catfish Production

Years	Bantul Production	Gunung Kidul Production	Kota Yogya Production	Kulon Progo Production	Sleman Production
Initial	7,028.00	6,747.00	22.00	7,645.00	13,909.00
0	7,028.00	6,474.00	22.00	7,645.00	13,909.00
1	8,267.08	12,428.55	56.36	23,495.75	24,299.78
2	8,321.69	7,268.79	58.51	20,970.61	14,212.41
3	10,589.98	18,842.06	74.64	17,499.22	30,172.56
4	10,625.27	17,407.79	56.20	17,307.44	69,707.56
5	10,129.84	15,629.49	51.30	16,010.34	56,664.03
6	9,751.71	14,363.00	47.74	15,053.02	48,509.46
7	9,460.15	13,435.44	45.10	14,333.34	43,044.03
8	9,233.56	12,742.10	43.10	13,784.79	39,208.15
9	9,056.40	12,215.89	41.57	13,362.25	36,428.06

4.7. Comparison of DIY Catfish Production, Demand, Supply Gap, and External Supply

According to Table 3, the relationship between DIY catfish production, DIY demand, and external supply highlights key dynamics for aquaculture development. In the initial year, DIY catfish production stood at 35,351 tons, covering only part of the 40,898.75-ton demand, leaving a 5,547.75-ton shortfall, which was fully supplied externally. Over time, demand rose significantly, reaching 82,184.82 tons in year 8, while local production could not keep pace, increasing reliance on external supply (7,173.13 tons in year 8). The continuous rise in demand underscores the need for local production optimization to reduce dependency on external sources.

Table 3: Comparison of DIY Catfish Production, Demand, and Supply Gap

Years	DIY Catfish Production	DIY Demand	Difference Between Demand and Production	Supply from Outside Regions
Initial		40,898/75	5,547.75	
0	35,351.00	41,553.13	6,202.13	5,547.75
1	35,351.00	42,217.98	-28,329.54	6,202.13
2	68,547.53	20,588.86	-30,243.14	0.00
3	50,832.01	98,783.39	19,604.93	0.00
4	77,178.46	106,850.66	-8,253.60	19,604.93
5	115,104.26	96,983.19	-1,501.80	0.00
6	98,485.00	90,209.63	2,484.70	0.00
7	87,724.93	85,485.56	5,167.51	2,484.70
8	80,318.05	82,184.82	7,173.13	5,167.51
9	75,011.70	79,908.79	8,804.62	7,173.13

4.8. Required Land Area

Table 4 shows fluctuating land area requirements: Initial demand: 128.89 ha, increasing to 144.09 ha in year 0. Negative values in years 1–2 due to overproduction capacity. Positive trend in year 6 (57.72 ha), rising to 204.55 ha in year 9. This trend reflects the close relationship between land requirements, demand growth, and production capacity, highlighting the need for land use optimization to ensure sustainable DIY catfish farming.

Table 4: Required Land Area for Catfish Farming

Years	Required Land Area
Initial	128.89
0	144.09
1	-611.69
2	-702.61
3	455.46
4	-191.75
5	-34.89
6	57.72
7	120.05
8	166.65
9	204.55

5. Conclussion

This study reveals that catfish production in DIY faces challenges in meeting the continuously increasing local demand due to population growth from 4,089,875 to 4,793,438 over ten years. Catfish production peaked in the fourth year at 115,104.26 units but declined in the following years, reaching 75,011.70 units in the ninth year, leading to an external supply requirement of 7,173.13 units. Land area requirements fluctuated, with negative values in the initial years before rising to 204.55 units in the ninth year, highlighting the importance of increasing land capacity to support production. Sleman and Kulon Progo emerged as the main production contributors, whereas Yogyakarta City had the smallest contribution. These findings emphasize the need for strategic policies focusing on productivity improvement, land management, and distribution to ensure the sustainability of the DIY catfish farming system.

The use of iThink enables dynamic modeling of the catfish farming system, illustrating interactions among key variables such as fish growth, feed consumption, mortality rate, and economic profitability. Through this modeling, farmers can identify the best strategies for feed management, stocking density, and environmental conditions to enhance productivity and operational efficiency. Overall, the dynamic modeling approach using iThink proves to be a valuable tool for planning and managing catfish farming, helping to improve production efficiency and reduce business risks.

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