Journal of Emerging Computer Technologies
Review Article
Received: *2025-02-24* | ***Reviewing:*** *2025-02-25 & 2025-07-16* | ***Accepted:*** *2025-07-20* | ***Online:*** *2025-07-23* | ***Issue Date:*** *2025-12-31*
Doi: 10.57020/ject.1645722

Multi-Criteria Recommender System for Optimization Product Based on Automatic Execution of Smart Contracts in a Blockchain Serious Game

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Abstract*— Agriculture is one of the main livelihoods in Indonesia. The country is a major producer of soybean and corn; however, the production output is still suboptimal due to the imbalance between consumption and production. This research integrates Multi-Criteria Recommender System (MCRS) for production optimization with blockchain-based smart contracts in the context of serious games. MCRS is used to evaluate various key factors to generate decision-making recommendations for farmers, optimizing production based on production and consumption levels, with the aim of maximizing farmers' stocks and meeting consumer needs. The approach is simulated in a serious game, with automatic execution of blockchain smart contracts using computer protocols without third-party involvement, ensuring transparency and data security in optimizing the entire production chain automatically and in real time. Optimization is performed using the Multi-Objective Optimization (MOO) method with a simplex function, where Z1 aims to maximize production based on average production, and Z2 aims to maximize production based on average consumption. The developed method uses Weighted Sum for decision-making value and Pareto Front method to optimize multiple issues by finding a solution that meets all objectives. The results showed that production optimization using simplex method resulted in values of Z1 = 7,591.044 and Z2 = 854.598 stocks per capita, with a trade-off value of 57.745. Using the simplex method for the optimization results of the average consumption of 854,598 stock per person/ per capita in 1 year based on the average consumption, it will get an average number of consumptions for soybean and corn commodity. These values indicate a significant increase in production efficiency as the system is able to maintain a balance between the production capacity of farmers and the consumption needs of the community. The Z1 value reflects the increase in stock availability from the farmers' side, while Z2 shows the efficiency in meeting per capita consumption needs. The trade-off value describes the optimal compromise point achieved between the two objectives, supporting the achievement of balance in the agricultural product distribution system. In addition, the implementation of blockchain technology in the agricultural production process contributes significantly to data transparency, security, and efficiency. By utilizing the Tezos Blockchain Network Environment, Unity 3D 2021.3.18f1, Solidity programming language based on Web 3 technology, and Redis Enterprise and MongoDB Compass databases, the system is able to record and execute transactions automatically without manual intervention. This strengthens trust between actors in the supply chain and supports a sustainable digital agriculture ecosystem.

Keywords*— Pareto Front, Simpleks, Data flow optimization, computational efficiency algorithm design, Multi-Criteria Recommender System, Blockchain, Serious Game

I. INTRODUCTION

We In the rapidly advancing digital era, game technology has developed and diversified. One example is the use of serious games as simulations and learning media to support operational management decision-making. The purpose of this serious game simulation includes modeling, input, and output activities to depict agricultural land, produce and sell products, and manage agricultural land [1, 2, 3]. One example is the game Wild West New Frontliner. This game involves collecting agricultural products such as corn, rice, and straw, which are then harvested and sold through a direct distribution system [4]. However, this game does not yet show the optimization results of production output, time, and consumption quantity. Therefore, the game can be used as a simulation to maximize production for farmers' decision-making in production. The Serious Game serves as the design for the learning medium in this serious game for simulation modeling, input, and objectives in this study.

According to data from BPS Indonesia in 2023, the production of soybeans and corn is very low. This is due to the current climate, global warming, crop failures, and an imbalance between consumption and production. As a result, imports are often necessary to meet the demand. The total corn production in 2023 was 14.6 million tons, a decrease from 16.53 million tons in 2022. Meanwhile, soybean production in 2023 was 550,000 tons, whereas the national demand is 2.7

Cite (APA): Putri, A. N., Harsad, P., Remawati, D., Rachmadi, R. F., Aditya, S. (2025). Multi-Criteria Recommender System for Optimization Product Based on Automatic Execution of Smart Contracts in a Blockchain Serious Game. *Journal of Emerging Computer Technologies*, 5(1), 57-69. Doi: 10.57020/ject.1645722

million tons, so production is far from meeting consumption needs [5].

In the manufacturing industry, there have been increasingly complex challenges in optimizing production processes. There is a demand to improve production efficiency, reduce costs, and maximize production. To address these challenges, innovative approaches such as the use of blockchain technology as a ledger management system in a decentralized blockchain network have been adopted. This network can only be accessed by relevant parties because the data is already integrated [6, 7, 8]. Blockchain technology in optimization uses distributed ledger as transparency of transactions in data tracing [9, 10].

A MCRS plays a crucial role in assisting companies in determining the optimal solutions that involve multiple variables and conflicting criteria. Implementation of serious games as simulations to achieve sustainable production goals [11, 12]. The MCRS is a recommendation system developed to account for multiple dimensions of user preferences or criteria when determining the most suitable recommendations for users. In MCRS, certain criteria or aspects can be integrated into the evaluation process, allowing the system to consider more than just an overall rating or score. Each criterion is analyzed separately and then combined using weighting methods or machine learning algorithms that prioritize aspects based on the specific preferences of the user. Unlike traditional recommendation approaches, which often assume that a single metric is sufficient to describe the quality or suitability of an item, MCRS recognizes that user needs are multidimensional and complex. Users may be seeking products or services that strike a balance across various criteria, and MCRS is capable of meeting this need with a more holistic approach. Through this approach, MCRS can identify recommendations that are more accurate and tailored to the specific needs of users, providing a more personal and relevant experience, and allowing for better adaptation to variations in user preferences.

The use of blockchain technology provides benefits for transparency, security, and automation of processes related to supply chains and manufacturing [9, 13]. Blockchain for games serves as an initial parameter in preparing explicit parameters for objective and measurable outcomes [14, 15, 16]. On the other hand, the concept of serious games can provide an interactive simulation environment and facilitate in-depth learning for stakeholders in the industry, optimizing multi-objective production processes more effectively.

Implementation of MCRS to helping farmers to determine the optimal solution that involves multiple variables and conflicting criteria. Some of the benefits of development using the simplex optimization method using Weighted Sum and Pareto Front, namely: Simplex Method is an optimization algorithm used to find optimal solutions to linear programming problems, Weighted Sum. Developing Simplex Method Using Weighted Sum, researchers can integrate different preferences from stakeholders [15, 17, 18]. Thus, allowing the weight adjustment for each objective variable, which helps in finding solutions that are more in accordance with preferences in decision making, the integration of Pareto Front allows the handling of multi-objective problems. The simplex method developed with Pareto Front can produce solutions that are in the Pareto Front, which is a solution that cannot be increased in one criterion without damaging performance in other criteria. So that helps in exploring the solutions space comprehensively and find optimal trade-off among various criteria. By combining weighted sum and pareto front in developing simplex methods [19, 20]. Can expand the reach for the application in this series of games in dealing with more complex problems and meet the needs of decision makers who have diverse preferences. So that it can increase flexibility and reliability of the simplex method in optimizing various types of problems [16, 21, 22, 23]. Transaction Blockchain using the Texos Blockchain Network Environment, Development Platform Unity 3D 2021.3.18f1, Programming Language Solidity based on Web 3 technology [24], Redis Enterprise Database, and MongoDB Compass.

II. RELATED WORK

Several studies related to Multi-Criteria Recommender System, Blockchain Technology, Serious Game, and Production Multi-Objective Optimization can be observed in Table I.

TABLE I. RELATED WORK OF THE RESEARCH ADOPTING BLOCKCHAIN TECHNOLOGY, SERIOUS GAME, AND PRODUCTION MULTI-OBJECTIVE OPTIMIZATION

Reference	Contribution	Object Research
(Bukhori, S,2020) [3]	Serious Game Supply Chain Management Agribusiness	Production Planning using Cournot Model
(Kim S.K., 2019) [7]	Blockchain for governance game	Blockchain game
(Park Y. B, 2005) [13]	An integrated approach for production and distribution planning in supply chain management	New Method for integration production
(Aouam, T., & Brahimi, N., 2013) [16]	Integrated production planning and order acceptance under uncertainty	A robust optimization approach
(Sohrabi, M. K., & Azgomi, H., 2020) [10]	A Survey on the Combined methods	Optimization Methods and Game Theory
(Abeyratne, S. A., & Monfared, R. P., 2016) [11]	Blockchain for manufacturing supply chain using distributed ledger	Blockchain and supply chain management
(Ishigaki, A., & Hirakawa, Y., 2016) [14]	Supply Chain Network using the Simplex Method	Two-objective Optimization
(Davtalab-Olyaie, M., & Asgharian, M., 2021) [17]	In the cross-efficiency evaluation	On Pareto-optimality
(Hamzé, N., Voirin, J., Collet, P., Jannin, P., Haegelen, C., & Essert, C., 2016) [21]	Automatic trajectory planning of deep brain stimulation	Pareto front vs. Weighted sum
(Putri, A. N., Hariadi, M., & Rachmadi, R. F., 2023) [22]	Multi-objective Optimization of Production	Method Simplex , Goal Programming , and Pareto Front Models
(Guo, Z. X., Wong, W. K., Li, Z., & Ren, P., 2013) [23]	Order scheduling problems in production planning	Modeling and Pareto optimization of multi-objective
(Zaizi, F. E., Qassimi, S., & Rakrak, S., 2023) [24]	The development of multi-objective recommender systems (MORS)	Recommendation of new methods with optimization approaches, such as deterministic and stochastic
(Migliorini, S., Carra, D., & Belussi, A., 2019) [25]	A travel recommendation system using a multi-objective optimization technique based on Simulated Annealing.	The distribution of tourists at various points of interest (POIs)
(Banerjee, A., Banik, P., & Wörndl, W., 2023) [26]	Evaluation of Tourism Recommender Systems from a Multi-Stakeholder Perspective	System recommendations based on the perspectives of tourists, service providers, and the community
(Davtalab, M., & Alesheikh, A. A., 2023) [27]	The learning similarity approach using Collaborative Filtering in location-based social networks.	A new method in recommending points of interest (POI)

This research is based on Serious Game with a design of Hierarchical State Finite Machine system and utilizes blockchain technology, and production optimization to maximize farmers' production based on production and consumption has never been done before. Therefore, the integration of developing serious games based on smart agriculture is needed to develop the simplex method with Z1 function to maximize production based on average production and Z2 to maximize production based on average consumption. The developed method uses Weighted Sum as a decision-making value and the Pareto Front method for optimizing multiple issues by finding solutions for all objectives. Researchers implement this serious game using blockchain technology as ledger storage and to track production availability and consumption levels, with a case study in Indonesia.

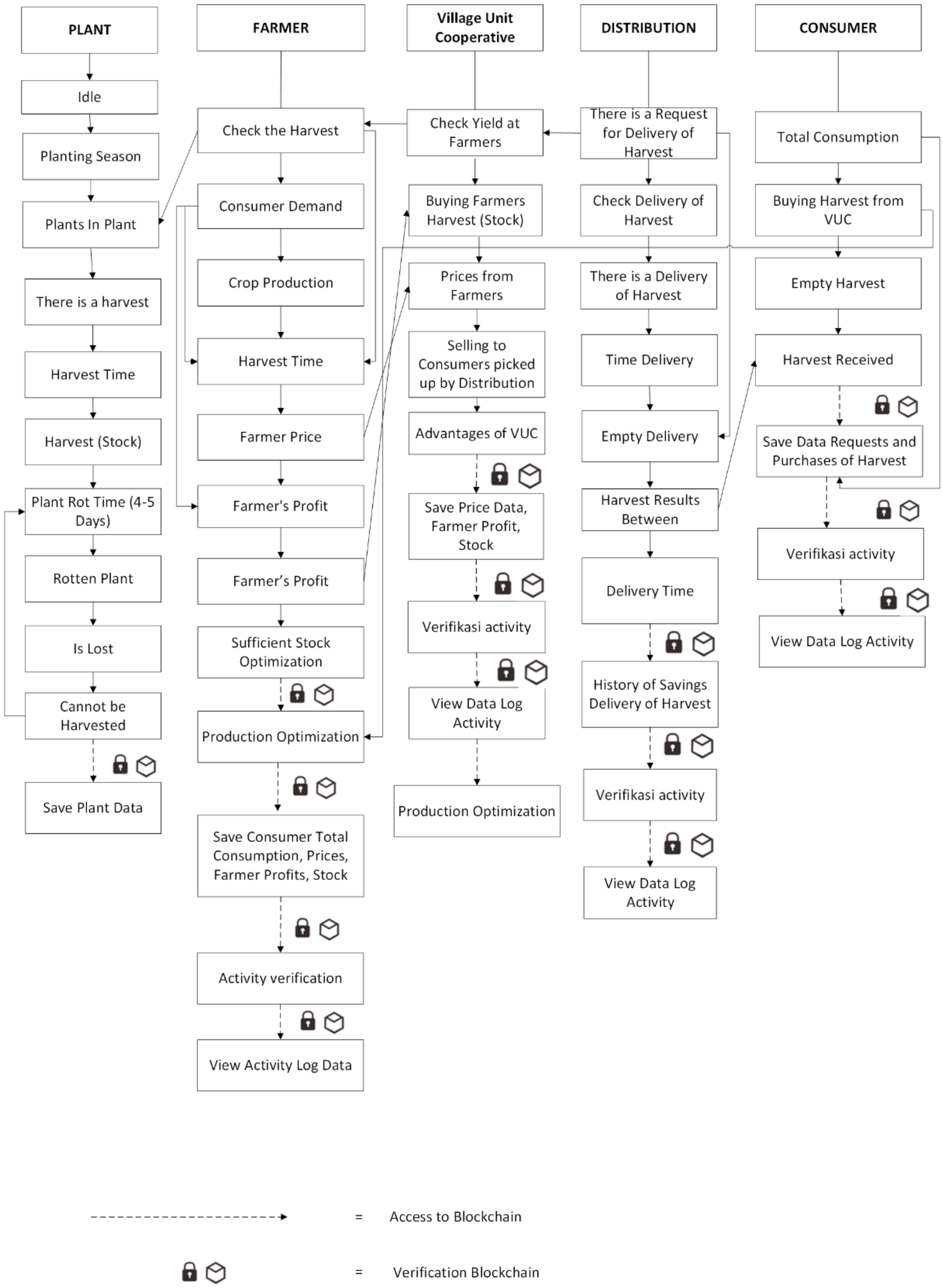

FIGURE I. HIERARCHICAL STATE FINITE MACHINE SERIOUS GAME BLOCKCHAIN BASED ON PRODUCTION OPTIMIZATION

III. METHOD

This research proposes a new method for implementation of MCRS, serious games, blockchain technology, and production optimization. In production optimization, it seeks the maximum value for soybean and corn production, so that stocks can meet the average consumption demand. Implementation of serious games on blockchain smart contracts, automatic execution smart contracts to optimize production carried out in several aspects of production, namely:

- Automatic execution smart contracts using automatic contracts via computer protocols without involving third parties in optimizing the entire production chain automatically and in real time based on the optimization results of the multi objective optimization (MOO) method using the selected simplex method with the objective function Z1 to maximize production based on average production and Z2 to maximize production based on average weighted-sum consumption, and Pareto front.
- Automatic Execution Smart contracts function as coordination between farmers and KUD based on the amount of production and the amount of consumption to ensure sufficient stock, this is applied to serious games.
- Automatic Execution Smart contracts as automatic payment transactions that can be automated with smart contracts. After completing the sale and purchase of farmers and KUD, the smart contract functions to agree on an agreement with the relevant parties by deploying contracts on the blockchain network and can be recorded and tracked transparently the origin of the product, this is applied to serious games Figure I illustrates the overview of the serious game in this research, starting from farmers opening agricultural land, planting, harvesting, selling to village cooperative units (KUD/VCU). VCU sells agricultural products to consumers. This serious game simulates farmer production based on production and the average consumption of society. Thus, the results obtained by farmers, consumers, and VCU have balanced optimization values.
- All these contributions confirm that this research not only focuses on optimizing agricultural production, but also creating a democratic and participatory system, where farmers have more control over their production decisions. Through integrating the latest technologies, this research makes a significant contribution towards solving the problems faced by the agricultural sector in Indonesia, while creating a model that can be adopted in other developing countries.

The design of the serious game based on Hierarchical State Finite Machine utilizes blockchain technology and smart contracts with the actors Farmer, VUC, and Consumer performing login transactions using the Metamask wallet connected to the blockchain network technology. In the Farmer menu, several activities are performed, such as planting agricultural seeds, checking stocks, checking the condition of plants to be sold (Harvest), and selling agricultural production to VUC. VUC buys agricultural products and resells them at the store, which are then purchased by consumers. Consumers buy harvested products from VUC and check the log activity of the harvest results from farmers, as shown in Figure II.

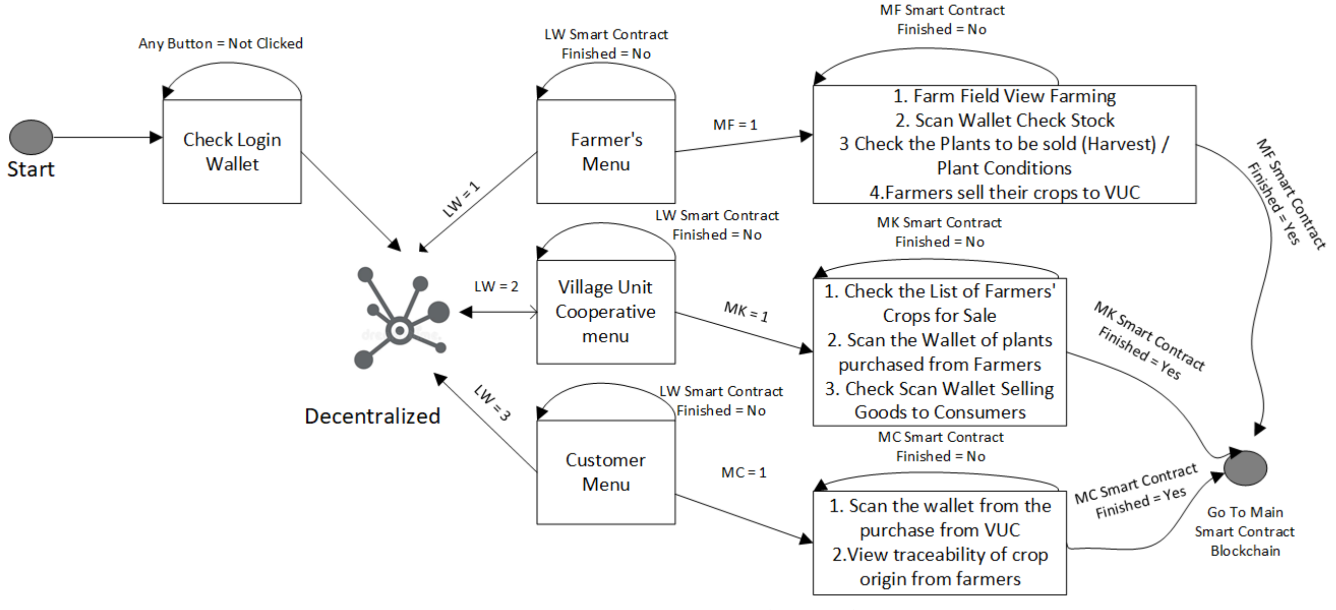

FIGURE II. MASTER OF BLOCKCHAIN SMART CONTRACT

The optimization method in the serious game uses agricultural production variables and consumption quantity. The optimization method employs simplex method to obtain function Z1 to maximize production based on average production and Z2 to maximize production based on average consumption in order to find the trade-off (opportunity cost) for both Z objectives. Points f A(X') and f B(X') represent the two objective functions to achieve the trade-off between the Total production and the average consumption quantity from A' to B. The key elements of the ideal point matrix are used to find the optimal value for all objectives [32]. Optimization in solving multi-objective problems. Subsequently, combining using the weighted sum method or scalarization [33] The weight values (W) serve as preferences in decision-making regarding the objectives to be attained. The value of W is varied as a parameter to generate a representative set using the Pareto front to obtain more optimal evaluations for each solution, as shown in Figure III.

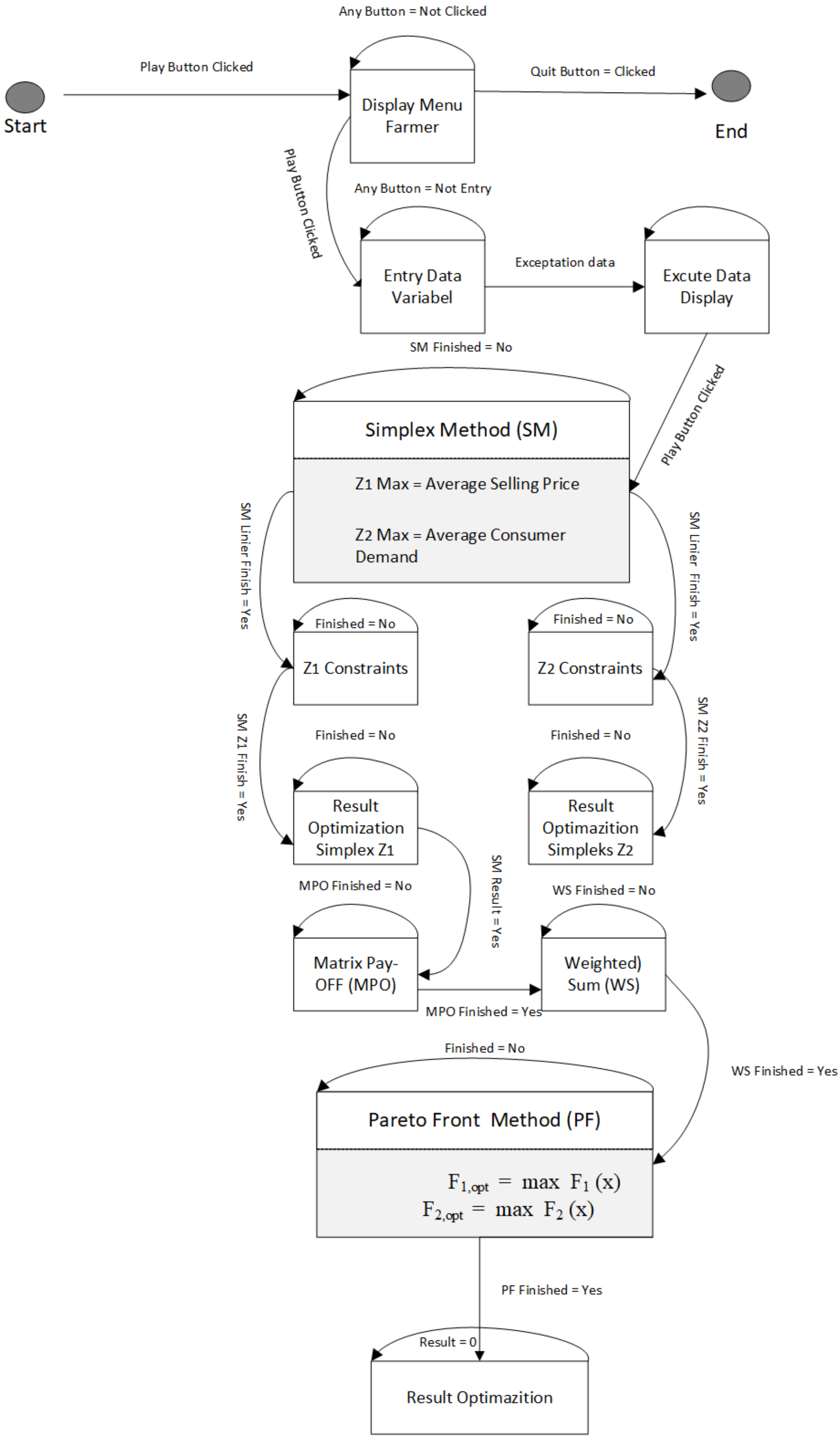

FIGURE III. SLAVE OF BLOCKCHAIN OPTIMIZATION PRODUCTION USING SIMPLEX AND PARETO FRONT

IV. RESULT AND DISCUSSION

The integration of MCRS with blockchain and the application of Weighted Sum and Pareto Front methods show significant potential in agricultural production optimization. The application of this algorithm is not limited to the context of agriculture in Indonesia but can be extended to various sectors in the real world, such as supply chain management, natural resource management, and the food industry.

Potential Applications of the Algorithm in the Real World

- Supply Chain Management: MCRS can be used to assist companies in determining vendor selection and delivery of goods by considering various criteria such as cost, delivery time, and product quality. By optimizing multiple criteria simultaneously, companies can make better decisions that result in efficiency and cost reduction.

- Natural Resource Management: In the context of forest or fisheries management, MCRS algorithms can help identify sustainable management practices. For example, by considering ecosystem sustainability and economic benefits, policies can be structured to maintain a balance between exploitation and conservation.

- Food Industry: In the food industry, these algorithms can optimize production and distribution processes by considering variables such as product quality, hygiene, cost, and consumer satisfaction. In new product development, the algorithm can be used to analyze consumer preferences from various aspects, so that the products produced are more in line with market demand.

Although the algorithm has great potential, there are some limitations that need to be considered:

- Data Complexity: The implementation of the MCRS algorithm and optimization methods such as Weighted Sum and Pareto Front require accurate and up-to-date data. Data quality is often a constraint, especially in rural areas where data may be unavailable or difficult to access.

- Technology Adoption: Many farmers, especially those operating on a small scale, may experience difficulties in adopting new technologies. Education and training on how to use blockchain-based systems and optimization algorithms are essential to ensure successful implementation.

- Infrastructure Challenges: The availability of digital infrastructure is also a significant challenge. In many areas, limited internet access may prevent widespread adoption of these technologies, despite their significant benefits.

- Resistance to Change: In many cases, there is resistance from stakeholders towards changing traditional methods. Building trust and understanding of the benefits of algorithm-based optimization is crucial for increased adoption.

In conclusion, despite the challenges and limitations, the application of MCRS algorithms with appropriate optimization methods has enormous potential to improve performance in various sectors, including agriculture. Further research and educational initiatives can help overcome these barriers, paving the way for a move towards more sustainable and efficient practices.

This serious game utilizes optimization methods to determine the production quantity to generate soybean and corn production outcomes based on production and consumption data using BPS (Statistics Indonesia) data for the Special Region of Yogyakarta, Indonesia, from 2019 to 2023. It employs simplex optimization with two objective functions as follows: Z_1 = Production Average Optimization and Z_2 = Optimization of Average Consumption. There are three essential elements:

- Decision Variables: These are the variables whose values are selected for the decision-making process, denoted as xi. The variables used include Average Consumption and Average Production.

- Objective Functions: These are the functions to be optimized (maximized/minimized). The maximization form of the linear programming model's objective function is as follows:

Constraints are the constraints that must be fulfilled. The equation for the constraint function of the simplex method is:

TABLE II. OPTIMIZATION VARIABLES

Term	**Description**
X_1	Soybeans
X_2	Corn
V_1	Production (person)
V_2	The amount of consumption (person)
V_3	Prices (kg)
V_4	Average of production
V_5	Average amount of consumption
V_6	Average of price
w_1	Weighted sum decision production
w_2	Weighted sum decision consumption

Solving in the simplex method is described in the simplex optimization table. It describes the overall algebraic function to make it easier to achieve an optimal condition described in Table II.

TABLE III. DATA BPS JOGJA, INDONESIA

No	**Basic Variables**	**Sub Element**	**The average person is based on data from the last 5 years**
1	X_1	V_4	1.54 Kg
		V_5	9.62 Kg
		V_6	Rp11.567
2	X_2	V_4	86.36 Kg
		V_5	0.86 Kg
		V_6	Rp 6.933

Examples of case studies:

Farmers produce to meet the needs of individuals as follows of soybeans 1.4 kg for per person, corn production 86.36 kg and average each person consumer soybeans 9.62 kg and average each person consumes 0.86 kg and the price of beans soybean Rp 11.567 and corn Rp 6.933

From these data requires an optimization method to maximize farmers' stock based on Z_1 based on average production and Z_2 based on the average consumption using the simplex method described in Table III.

Settlement with the simplex method is explained in the simplex optimization table. Explain the overall algebra function to make it easier to achieve the optimal conditions described in Table IV.

TABLE IV. INEQUALITY BECOMES AN EQUATION IN SIMPLEX OPTIMIZATION AVERAGE CONSUMPTION Z_1 OPTIMATION AND Z_2 PRODUCTION AVERAGE OPTIMIZATION

	X_1	X_2	RHS	Equation Form Z_1	X_1	X_2	RHS	Equation Form Z_2
Max (Z_1 and Z_2)	1.54	86.6		$Z_1 = 1.54\ V_4 X_1 + 86.36\ V_4 X_2$	9.62	0.86		$Z_2 = 9.62\ X_1 + 0.86\ X_2$ (V_5)
Constraints: V_5	1	1	<= 10.48	$X_1 + X_2 <= 10.48$	1	1	<= 10.48	$X_1 + X_2 <= 10.48$
Constraints: V_4	1	1	<= 87.9	$1\ X_1 + 1\ X_2 <= 87.9$	1	1	<= 87.9	$1\ X_1 + 1\ X_2 <= 87.9$

Solving with the simplex optimization method with the iteration steps in Table IV. is Literations Z_1 Optimization of Average Consumption and Table V. Literations Z_2 Production Average Optimization.

The steps in the iteration include 5 stages

- Determine the entering variable = Choose the coefficient value of the objective function with the most significant negative absolute value and, after this, refer to it as the pivot column.
- Determine the leaving variable = Look for the coefficient comparison value from the right side of the limit function in the pivot column value in each row. Selects the comparison value of the value with the most minor positive. Mark each row with the smallest ratio and name the pivot row.
- Determine the pivot number from the intersection of the pivot row and column

Table V The function of Z_1 to maximize production based on the average production steps is as follows:

Changing functions and objectives as well as constraints:

Objective Function = $Z_1 - 1.54\ X_1 - 86.36\ X_2 = 0$

The constraint function is changed to equality & added with slack variables or additional variables representing the capacity which is a constraint. Constraint Function:

$$X_1 + X_2 + r = 10.48$$

$$X_1 + X_2 + s = 87.9$$

Initial simplex table, show in Table V.

TABLE V. INITIAL SIMPLEX

Basic Variables	X_1	X_2	r	s	t	NK/ Solution
Z_1	-1.54	-86.36	0	0	0	0
R	1	1	1	0	0	10,48
S	1	1	0	1	0	87,9

Table VI below shows selecting the key column to find the Largest Negative (Pivot Column) and finding the smallest ratio by dividing the solution by X_1.

TABLE VI. LARGEST NEGATIVE

Basic Variables	X_1	X_2	r	s	t	NK/ Solution	Basic Variabl es
Z_1	-1.54	-86.3	0	0	0	0	Ratio
R	1	1	1	0	0	10.48	10.48
S	1	1	0	1	0	87.90	87.9

Table VII. Finding the smallest ratio and obtaining the pivot value, the smallest ratio is 87.9 and the pivot value is obtained as 1.

TABLE VII. SMALLEST RATIO

Basic Variables	X_1	X_2	r	s	t	NK/ Solution	
Z_1	- 1.54	- 86.36	0	0	0	0	Ratio
R	1	1	1	0	0	10.48	10.48
S	1	1	0	1	0	87.90	87.9

After obtaining the pivot value, it can be divided by the Pivot Value or divided by 1 described in Table VIII.

TABLE VIII. DIVIDED BY THE PIVOT

Basic Variables	X_1	X_2	r	s	t	NK/ Solution	Ratio
Z_1	- 1.54	- 86.36	0	0	0	0	
r	1	1	1	0	0	10.48	10.48
X1	1	1	0	1	0	87.9	87.9

Next Table IX, change the values of the key rows or Make Column X1 Become 0 The values of the key rows are changed by dividing them by the key number as shown in the table below with the formula.

TABLE IX. KEY ROW VALUE

Basic Variables	X_1	X_2	r	s	t	NK/ Solution
Z_1	0	-84.82	0	1.54	0	135.366
X_2	0	0	1	-1	0	-77.42
X_1	1	1	0	1	0	87.9

Next is to Make Z become non-negative. So, the table cannot be further optimized, and it represents the optimal result. At this stage, Z still has negatives in X2, so it is repeated again like Step 4 to find the smallest ratio, which is 0, and the ratio is 0.

Repeat Step 4 after finding the pivot and the smallest ratio, then Make Column X_2 Become 0 with the formula New row = old row - (coefficient in the key column) x new key row value as follows ((Row Z) + 84.82(Row X_1), Unchanged. Show in Table X.

TABLE X. REPEAT STEP

Basic Variables	X_1	X_2	r	s	t	NK/ Solution
Z_1	0	0	0	86.36	0	7591.044
r	0	0	0	0	0	0
X_1	0	1	0	1	0	87.9

If Column Z1 no longer has negatives, then the result can be obtained, indicating that the result is already optimal.

TABLE XI. OPTIMAL RESULT

Basic Variables	X_1	X_2	r	s	t	NK/ Solution
Z_1	0	0	0	86.36	0	7591.04
X_2	0	0	0	0	0	0
X_1	0	1	0	1	0	87.9

In Table XI Solutions to be based on the average production of soybean and corn commodities, it will get Z_1 = 7.591.044 for per capita/per person in 1 year

Solutions for Z_2 Problems Using Simplex Method Z_2 to maximize production based on average consumption. Changing the functions, objectives, and constraints:

Objective Function = Z_2-9.62 X_1 – 0.86 X_2 = 0

Function of Limitation:

$X_1 + X_2 + r = 10.48$

$X_1 + X_2 + s = 87.9$

Initial simplex table in Table XII, Selecting the key column to find the Largest Negative (Pivot Column) and Finding the smallest Ratio by dividing the solution by X1.

TABLE XII. INITIAL SIMPLEX

Basic Variables	X_1	X_2	r	s	t	NK/ Solution
Z_2	-9.62	-0.86	0	0	0	0
r	1	1	1	0	0	10,48
s	1	1	0	1	0	87,9

Table XIII shows finding the smallest ratio by dividing the solution by X1.

TABLE XIII. SMALLEST RATIO

Basic Variables	X_1	X_2	r	s	t	NK/ Solution	Ratio
Z_2	-9.62	-0.86	0	0	0	0	
r	1	1	1	0	0	10.48	10.48
s	1	1	0	1	0	87.90	87.9

Table XIV shows finding the smallest ratio and obtaining the pivot value, resulting in the smallest ratio of 87.9 and obtaining the pivot value of 1.

TABLE XIV. SMALLEST RATIO AND OBTAINING THE PIVOT VALUE

Basic Variables	X_1	X_2	r	s	t	NK/ Solution	Ratio
Z_1	0	-84.82	0	1.54	0	135.366	
X_2	0	0	1	-1	0	-77.42	0
X_1	1	1	0	1	0	87.9	87.9

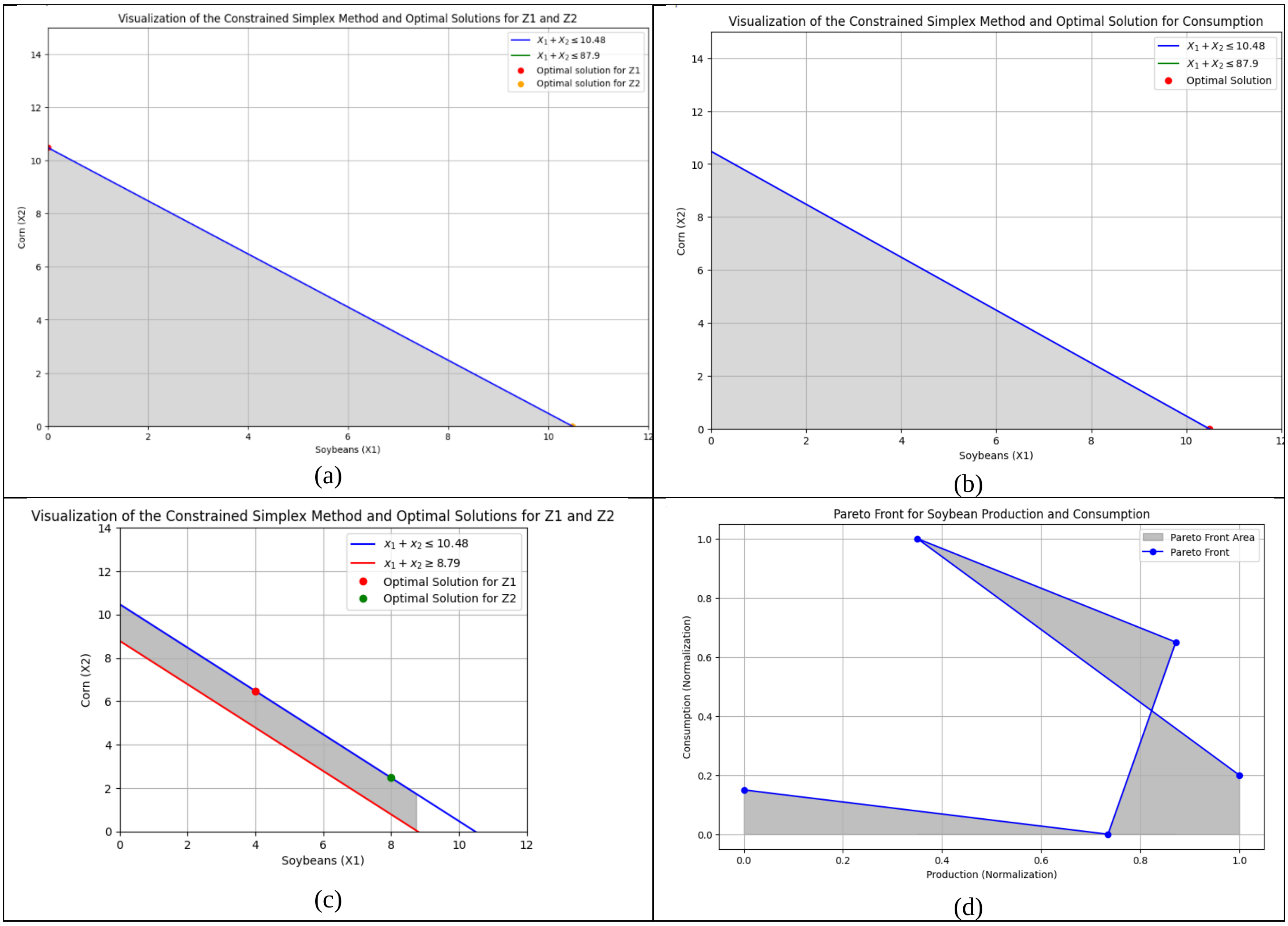

FIGURE IV. GEOMETRIC REPRESENTATION OF THE SIMPLEX METHOD
(A) Objective Function Z1 Solution Based on Average Production of Soybean and Corn Commodities
(B) Objective Function Z2 Solution Based on Average Consumption of Soybean and Corn Commodities
(C) Combination of Objective Functions Z1 And Z2 Based on Average Production and Average Consumption of Soybean and Corn Commodities
(D) Pareto Front

Next table XV, changing the values of the key rows or Making Column X1 Become 0. The values of the key rows are changed by dividing them by the key number as shown in the table below using the formula New Row = Old Row - (coefficient in the key column) x new value of the key row as follows ((Row Z) + 9.62(Row X1), (Row r) -1 (Row X1), Unchanged).

TABLE XV. CHANGING THE VALUES OF THE KEY ROWS

Basic Variables	X_1	X_2	r	s	t	NK/ Solution
Z_2	0	8.76	0	9.62	0	845.598
X_2	0	0	1	-1	0	-77.42
X_1	1	1	0	1	0	87.9

If Column Z no longer has any negatives, then the result can already be obtained, indicating that the result is optimal showing in Table XIV.

TABLE XVI. RESULT

Basic Variables	X_1	X_2	r	s	t	NK/ Solution
Z_2	0	8.76	0	9.62	0	845.598
X_2	0	0	1	-1	0	-77.42
X_1	1	1	0	1	0	87.9

In Table XVI the solution to be based on the average consumption, will get an average number of consumption of soybean and corn commodities Z_2 = 854.598 stock per person/ per capita in 1 year

For example, in corn: $A'B' = \frac{f\,A(X') - f\,A(X'\prime)}{f\,B(X') - f\,B(X'\prime)}$ (3)

$f\,A(X')\ dan\ f\,B(X')$ What are two objective functions; Therefore, trade-off between production and the amount of consumption A' B' In corn is

$$Z\ A'B' = \frac{100.67 - 60.248}{1.4 - 0.7} = 40.422 / 0.7 = 57.745$$

In efficient variable is a transformation curve that measures the correlation between two objective functions described in Figure IV. Line slope A'B' dan B'C' Reflecting trade-offs between the two objectives. For example, Z each production results in the amount of consumption of corn, which is 67.75 stock per capita/per person. The amount of trade-off must be considered when making decisions. The payment matrix for the two objectives is shown in Table XVII.

TABLE XVII. MATRIX PAY-OFF ON X_2

	V_2	V_1
V_1	1.4	100.67
V_2	0.7	60.248

The first row is the maximum value of consumption (1.4) based on production (100.67), the second row is the minimum value of production (60.248) based on the amount of consumption (0.7) in corn.

$f\,A(X')\ dan\ f\,B(X')$ What are two objective functions; Therefore, trade-off between production and the amount of consumption A' B' in soybeans is

$$Z\ A'B' = \frac{2.33645 - 0.13908}{10.5 - 8.8} = 2.19737 / 1.7 = 1.29257$$

The efficient variable is a transformation curve that measures the correlation between two objective functions. Line slope A'B' dan B'C' Reflecting trade-offs between the two objectives. For example, Z each production results in the amount of consumption of soybeans, which is 1.9257 stock per capita/per person. The amount of trade-off must be considered when making decisions. The payment matrix for the two objectives is shown in Table 18 below

TABLE XVIII. MATRIX PAY-OFF ON X_1

	V_2	V_1
V_1	10.5	2.33645
V_2	8.8	0.13908

The first row is the maximum value of consumption (10.5) based on production (2.33645), the second row is the minimum production value (0.13908) based on the amount of consumption (8.8) in soybeans.

Multi-Objective Optimization (MOO) problems often solve several goals by combining them into a single-goal scalar function. The simplest and the most common selected approach is the weighted-sum or scalarization method [33], defined as:

Minimize u(x) $= \sum_{i=1}^{q} WiFi\ (x)$ (4) $\boldsymbol{x} \in \boldsymbol{S}$

That represents a new optimization problem with the unique objective function u(x). Note that the decision-maker usually sets the weight wi (Navon et al., n.d.), such as $\sum_{i=1}^{q} wi = 1$ and $wi \geq 0\ \forall i$. Graphically, the new goal function u(x) is a 1-dimensional criterion hyperplane. For a two-goal problem, the new goal function u(x) is a straight line in the field of f_1-f_2. Note that the Weighted sum decision production and Weighted sum decision consumption determine the slope of the straight line. The optimal solution is the tangent point of the straight line that intersects with the front of Pareto from the feasible criterion space [26].

TABLE XIX. WEIGHTED SUM DECISION

Optimal point	w_1	w_2
a	0.1 – 0.4	0.6 - 1.0
b	0.1 – 0.4	0.6 - 1.0
c	0.1 – 0.4	0.6 - 1.0

Multiple problem solving, or MOO, decision-making is aided by optimization techniques. Since the simplex approach produced a MOO problem, the Pareto Front approach is required to optimize the optimization procedure. The Weighted-Sum Method, which combines all production-maximizing objectives into a single objective function by first weighting each objective function and then adding (+) with an efficient set derived from parametric changes of the weights, was made possible by the Pareto front's creation. For instance, consider the production maximizing problem where the objective is to maximize q. [26]:

$$\text{Max } w_1 Z_1(x) + w_2 Z_2(x) + \ldots\ldots\ldots + w_q z_q(x) \quad (5)$$

subject to: x € f w ≥ 0

The counting results for Z_1 and Z_2, as well as the weighted sum, Z_1 Price Optimization for Farmers Benefits

Z_2 Optimization of Average Consumption. Interpretation of the efficient variable with an extreme point for Pareto.

$$\text{Year 2023 – 2019} = \text{Max } w_1 (10.50\, x_1 – 0.14\, x_2) + w_2 (60.25\, x_1 – 0.70\, x_2) \quad (6)$$

subject to: $x \in f$

$w_1, w_2 \geq 0$

$$\text{Max } w_1 (10.50\, x_1 – 1.72\, x_2) + w2 (78.97\, x_1 – 0.70\, x_2) \quad (7)$$

subject to: $x \in f$

$w_1, w_2 \geq 0$

$$\text{Max } w_1 (9.80x_1 - 2.34x_2) + w_2 (96.66\, x_1 – 0.70\, x_2) \quad (8)$$

subject to: $x \in f$

$w_1, w_2 \geq 0$

$$\text{Max } w_1 (8.50\, x_1 -2.17\, x_2) + w_2 (100.67\, x_1 – 1.40\, x_2) \quad (9)$$

subject to: $x \in f$

$w_1, w_2 \geq 0$

$$\text{Max } w_1 (8.80\, x_1 -1.31x_2) + w_2 (95.25\, x_1 – 0.80\, x_2) \quad (10)$$

subject to: $x \in f$

$w_1, w_2 \geq 0$

The results of the calculation of Z_1 and Z_2 based on commodities to maximize stock based on production and the amount of consumption using w.

Application of Optimization on the Pareto front to determine solutions to multi-objective problems. The optimal Pareto front is a line that connects two objective function contours that cannot change from a constrained problem. Optimization of the Pareto front is centered on design, and the criterion space in the criterion space is often referred to as one point.

In Figure IV, the Pareto front optimization method demonstrates the optimization of the weighted sum of values obtained from the weighted sum [27]. The value Z_1 provides a solution to optimize production based on average production, while the optimization value Z_2 provides a solution to optimize production based on the average consumption. The Pareto front optimization solution for soybean and corn criteria on Z_1 and Z_2 in graphical form can be seen in the figure IV.

Application of Pareto Front Optimization to determine multi-purpose problem solutions. The optimal front of the pareto is a line that connects the two contours of the objective function that cannot change from a limited problem. Pareto front optimization is centered on the design, and the criteria space in the criteria space is often referred to as one point.

The results of Blockchain Implementation and Production Optimization can be seen in Table XX.

TABLE XX. TRANSACTION ON FARMER AND KUD

Farmer ID	TxnHash Transaction Sale	Signature
tz1WT8DZ. ..jihyz	ooG8AGQGL4LPMHP aanjpLJ37y9mU...VagcStke	sigjo1HXpLHdHiYpwzFuzhRpMzzfyzJ1MR2Gpe3tuyt3YQu4jepRDb 7XCCLTV4T3VPqhnxDbwChkPSH5Lf4qhfmUmEXUa5yt
tz1cxZNE... QswDN	opDDVh2dKKpbGsWF bXv7i8q6mfGk...249w458w	sigUgVcRjFuEW8Dtf46zLSLTuJqUbEirqHtAU5H9qHSujiDSjDvw6j Rf5bRb8Vrsk8bEePuaFFLLoew2rKNSxcWTrKAcg8UB
tz1WT8DZ. ..jihyz	opMhi5aAdcbdxezvPKrAv 4YE3Wuy...ycTA554Z	sigjp7fWNzykn7ZC5ZFJ8TY42Ktwvn6JHCPztptAJpaVYMkB4ugjA9 kRPAYkXaiqAx87MjBSg5cHFjcz4g3K2STtXjMej2Zs
...	...	...

V. IMPLEMENTATION OF BLOCKCHAIN TECHNOLOGY

The development of this serious game contains three principles, Learning, Rule and Play. This aims to enable users to take advantage of the following benefits.

A. *Learning*

The learning level in this Serious Game starts from the Supply chain Management flow process using Smart Agriculture-based Blockchain using a production optimization method through cutting distribution flows using the simplex method. Optimization modeling of new distribution chain flows such as Farmers, KUD, Distribution and Consumers using simplex and Pareto methods to get maximum stock. So that stock is fulfilled by using Blockchain.

B. *Rule*

The rules in this Serious Game are very necessary as basic rules to approach the issues raised in the game. Reality or facts are very important in implementing a mandatory rule (Rule of the game), so that the interactions obtained later are truly in accordance with events in the field. The rules in this serious game can be fidelity (depth) because it is physical fidelity but rather function fidelity because it tends to rule on data scenarios in the form of values.

The rules in this Serious Game Supply Chain Management Using Automatic Execution Blockchain Smart Contract are the results of optimizing production results using the Simplex and Pareto Methods through two optimizations, the first for sufficient stock from the products produced by farmers. The second optimization is to maximize farmer stock. The variables used for optimization are Average Total Consumption Parameters, Production / Stock Parameters in Farmers and KUD.

The following are the actors involved in Blockchain.

- Farmers: Actors who produce crops and sell in quantities (kilograms/quintals/tons) to KUD.
- KUD/Retailer: Purchase in quantities (kilograms/quintals/tons) from farmers who will sell to consumers, monitor and evaluate each sales transaction.
- Distribution: Delivery of goods (connecting chain between KUD and consumers)

- Consumer: Party who buys from KUD for consumption or resale. (Restaurant, market or individual)

  Following is the Blockchain framework design

- Assets: Farmers and KUD carry out the sales process then KUD monitors and evaluates each sales transaction, KUD sells to consumers through distribution parties
- Participants: Farmers, Distribution Cooperatives, Consumers
- Transactions: Traceability of information about stock, consumption quantities, optimization of new distribution channels to optimize production.

  Commodities: Production Optimization, Harvest Results.

C. Play

The game design in this research uses BPS data that has not yet been processed, so it will be modeled in game play. As previously discussed, the data will be in the process of optimizing production results, so as to obtain maximum results according to consumer and KUD needs. The optimization value obtained will be processed using Blockchain technology which has very private data, the information and transactions obtained can only be accessed by the parties involved without passing through a third party so it is safe, the data history cannot be deleted and can only be accessed by the relevant block parties and requires related user verification seen on Figure V.

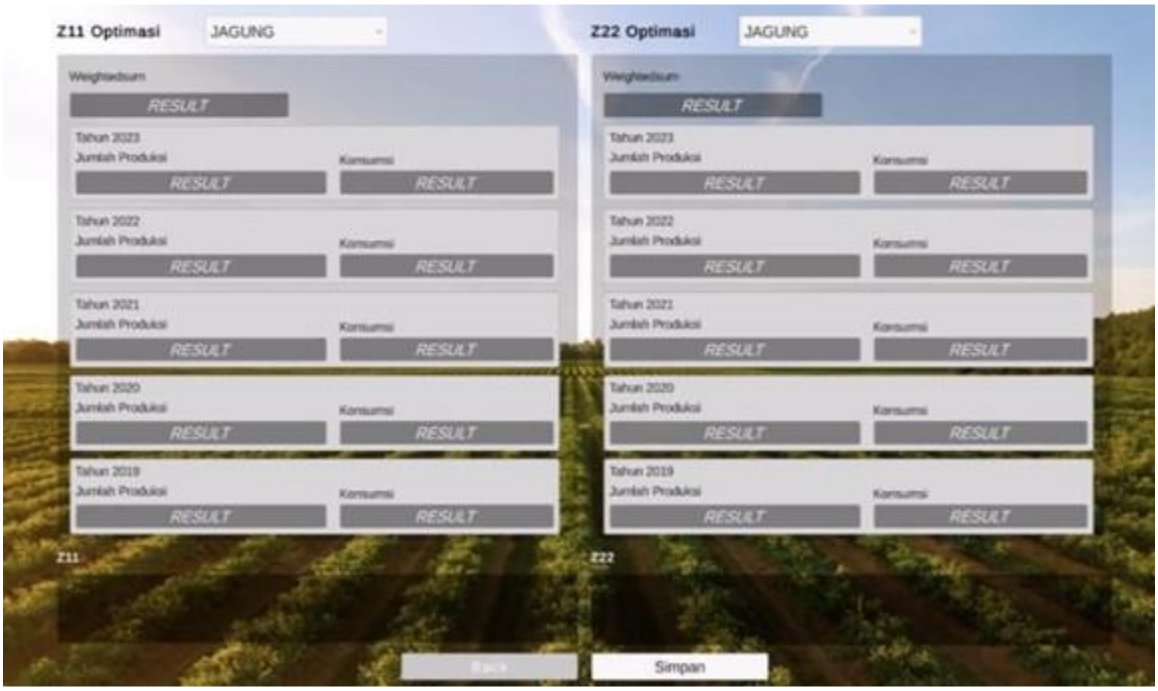

FIGURE V. IMPLEMENTATION OF PRODUCTION OPTIMIZATION IN BLOCKCHAIN TECHNOLOGY

The following is Algorithm I: Pseudocode of Transaction Blockchain using the Texos Blockchain Network Environment, Development Platform Unity 3D 2021.3.18f1, Programming Language Solidity based on Web 3 technology, Redis Enterprise Database, and MonggoDB Compass.

ALGORITHM I: PSEUDOCODE OF TRANSACTION BLOCKCHAIN

{"protocol":"PtNairobiyssHuh87hEhfVBGCVrK3WnS8Z2FT4ymB5tAa4r1nQf",
"chain_id":"NetXnHfVqm9iesp",
"hash":"ooG8AGQGL4LPMHPaanjpLJ37y9mUUkRJJNY2XN8k7mmVagcStke",
"branch":"BLktRxQiqinUYCR2zMfzEyVSxPBvd9cCisk4881CeZU57q4dXBo",
"contents":[{"kind":"transaction","source":"tz1WT8DZ6xw3BY3w7K6yHAaVCmvyPGojihyz","fee":"417",
"counter":"22442546","gas_limit":"1000","storage_limit":"41",
"amount":"0","destination":"KT1WguzxyLmuKbJhz3jNuoRzzaUCncfp6PFE",
"parameters":{"entrypoint":"addToMarket","value":{"prim":"Pair","args":[{"prim":"Pair","args":[...]},{"int":"38"}},
"metadata":{"balance_updates":[{"kind":"contract","contract":"tz1WT8DZ6xw3BY3w7K6yHAaVCmvyPGojihyz",
"change":"-417","origin":"block"},
{"kind":"accumulator","category":"block fees","change":"417","origin":"block"}],
"operation_result":{"status":"applied",
"storage":{"prim":"Pair","args":[{...},{...}]},
"balance_updates":[{"kind":"contract","contract":"tz1WT8DZ6xw3BY3w7K6yHAaVCmvyPGojihyz",
"change":"-10250","origin":"block"},{"kind":"burned","category":"storage fees","change":"10250","origin":"block"}
],"consumed_milligas":"899645","storage_size":"61621",
"paid_storage_size_diff":"41",
"lazy_storage_diff":[{"kind":"big_map","id":"182373","diff":{...}},{"kind":"big_map","id":"182372","diff":{...}
},"kind":"big_map",
"id":"182371","diff":{...} }]}}}],
"signature":"sigjo1HXpLHdHiYpwzFuzhRpMzzfyzJ1MR2Gpe3tuyt3YQu4jepRDb7XCCLTV4T3VPqhnxDbwChkPSH5Lf4qhfmUmEXUa5yt"}

VI. CONCLUSION

This research successfully integrates the MCRS with blockchain technology and optimization methods in the context of serious games to optimize agricultural production, especially in soybean and corn commodities in Indonesia. The results obtained show that the application of these algorithms and technologies can help achieve a balance between production and consumption, and improve food security in a country with significant challenges in the agricultural sector.

When compared to recent research using similar approaches, this study shows some important contributions. For example, research by Mahmudy [23] in agricultural product storage optimization using genetic algorithms showed positive results in improving efficiency, but did not consider the complex multi-criteria decision-making aspects required by farmers. This research fills the gap by offering an MCRS that considers multiple criteria simultaneously, serving not only as an enthusiast tool but also as a strategic guide for decision-making.

Furthermore, the study by Huang [24] illustrates the application of blockchain technology in the food industry, highlighting the transparency it offers in the supply chain. However, the research did not integrate a recommendation system for the decision-making stage at the farm level. In this case, our research not only brings transparency through blockchain but also improves efficiency through MCRS coupled with the implementation of smart contracts, providing a more practical and innovative way of managing agricultural production.

Another contribution of this research lies in the use of the simplex method for two different optimization objectives-increasing average production and meeting average consumption. This approach focuses on dual objectives, which are not widely discussed in previous literature. With the use of Weighted Sum and Pareto Front methods, we find a balance between the different objectives, providing a more holistic and adaptive approach to the challenges faced by farmers.

In order to enhance the position of this study within the existing literature, we recommend further research to test the implementation of MCRS and blockchain technology in different agricultural contexts and look at the impact on broader agricultural practices. Future research could also explore the potential for integration with artificial intelligence technologies to improve the accuracy of predictions in decision-making models.

Overall, this research adds new insights into the use of technology and algorithms to support better decision-making in agricultural production, paving the way for more sustainable and efficient practices in the face of global challenges in the food sector.

AKNOWLEDGEMENNT

The authors would like to thank the Telematics Laboratory, Institut Tecnology Sepuluh Nopember, Surabaya and Universitas Semarang for suport this research.

DATA AVAILABILITY

The data supporting the findings of this study are available upon request from the authors.

FUNDING

No funding was received for conducting this study.

AUTHORS' CONTRIBUTIONS

All authors contributed equally to this work.

CONFLICTS OF INTEREST

No conflict of interest was declared by the authors.

ETHICAL STATEMENT

In this article, the principles of scientific research and publication ethics were followed. This study did not involve human or animal subjects and did not require additional ethics committee approval.

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