Predicting the Need for Agricultural Land to Support Food Security in Blangkejeren District Through a Dynamic System Approach

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ABSTRACT : *This research is critical because accurately predicting future land requirements directly impacts food security in the region. The government and interested parties can make more precise and strategic planning by projecting land needs. This allows for optimal land allocation for various purposes, such as farming, housing, and more. This study focuses on Blangkejeren District to estimate the demand for rice fields in the future to support food security in the sub-district. Complex data analysis is performed using Powersim Studio 10 Express software to develop the model. Primary information comes from related agencies like the Gayo Lues Central Statistics Agency, Bappeda Gayo Lues, and the Gayo Lues Agriculture Office. The yearly additional predicted rice field area for Blangkejeren District shows a steadily increasing trend from 2025 to 2045. In 2025, the extra rice field region was estimated to be approximately 1818.64 hectares. This prediction demonstrates a consistent annual growth, with an additional rice field area attaining over 2677.78 hectares by 2045. The study results show that population expansion in Blangkejeren District from 2025 to 2045 will cause a significant rise in food demand, which also carries implications for land needs. On that basis, sustainable and strategic planning in land administration and improving agricultural efficiency is the key to ensuring future community welfare and food security.*

KEYWORDS -*Agricultural land, dynamic system, food security, predicting*

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I. INTRODUCTION

With a large archipelago and diverse climatic conditions, Indonesia has great potential in the agricultural sector of food crops and is also known as an agricultural country[1]. Food crop agriculture plays an essential role in maintaining national food security and is a source of livelihood for most of the population who work as farmers [2].

Blangkejeren District, which is located in the Gayo Lues Regency area, is one of the areas that has great potential in agriculture, especially in supporting local food security [3]. Data on rice fields in Gayo Lues Regency covering an area of 4855 hectares spread across 11 sub-districts [2]. Meanwhile, the area of rice fields in Blangkejeren District is 791.25 Ha [2].

Over time, the existing area of rice fields will not be able to support the population growth, which is increasing every year and will be followed by an increase in food needs. This condition is also exacerbated by the decline in rice production in the district by 40.42%. Blangkejeren also contributes to overall rice productivity [5[5][6]. The decline in rice production can threaten local food security, which may affect food sovereignty in the future [2],[6]. Will we remain silent with conditions like this? Of course not; a planner or researcher must be able to make careful planning, one of which is to predict future land needs so that the population's food needs are met.

This research is necessary because it predicts the future need for agricultural land directly impacts food security in a region[7]. The government and stakeholders can make more accurate and strategic planning by estimating land needs. In addition, this is also an effort to support the government in eradicating hunger as one of the crucial targets of the 17 Sustainable Development Goals (SDGs) by 2030[8].

II. METHODOLOGY

2.1. Research Design and Data Sources

In this study, the researcher uses a quantitative approach as the basis of research. This method is often used to test hypotheses, measure variables, and determine the relationship between variables. The data is usually in numbers, such as survey results, experimental data, and statistics. This research focuses on Blangkejeren District to predict the future need for agricultural land to support food security in the sub-district. The data analysis process uses Powersim Studio 10 software to conduct a model. Primary data is from related agencies such as the Gayo Lues Central Statistics Agency, Bappeda Gayo Lues, and the Gayo Lues Agriculture Office.

2.2. Data Type

The data used are population data in 2023, which is 31924 people. In 2022, it is 31383 people. In 2021, it is 30930 people; in 2020, it is 31180. Furthermore, the percentage of change data is the average annual comparative changes in the population. In this study, the average percentage of population change is 1,443%. The change in question is the change in the population each year, which is calculated based on the constant percentage of population change. Rice constant data is in the form of the amount of rice consumed by each population, with a value of 265 kg/person/year [2].

The data on the area of original rice fields, namely existing rice fields in 2023, is 791.25 Ha. Meanwhile, the area of the Blangkejeren sub-district is 16605.44 Ha. The land and rice conversion is the constant value converted from the area of rice fields in Ha to rice successfully produced in kg.
The report of the Central Statistics Agency states that the amount of conversion from rice field area to milled dry grain (GKG) is 5.257843137 [9]. The Central Statistics Agency report also states that the amount of conversion from dry milled grain (GKG) for the Aceh Province area is 0.6395 [9]. Then, the conversion amount from tons to kg is 1000 (1 Ton = 1000 kg), so the conversion of land to rice results from the multiplication of 5.257843137*0.6395*1000 or 3362.390686.

The rice production in question is the result of multiplying the area of the original rice field with the conversion of land and rice. The difference between Demand and Production in question is the difference between the need for rice and the amount of rice produced, and the area of Additional Rice Fields in question is the amount of rice field area needed to meet rice needs without the need to buy/import from other regions. The value of the additional rice field area is obtained by dividing the difference between demand and production by the conversion value of land and rice.

2.3. Data Analysis

The data analysis process uses Powersim Studio 10 software to perform a model [10], [11],[12],[13]. The model built is a variable that affects each other over some time. Each variable corresponds to a quantity with a numerical value and is already a part of itself.
Causal Loop Diagram, often abbreviated as CLD, refers to the characteristics of the system as mentioned in the previous section, namely the presence of supporting elements, internal or external feedback, and equilibrium. CLD is a pre-condition before proceeding with the flow diagram process in Dynamic System software, namely Powersim Studio 10[14].
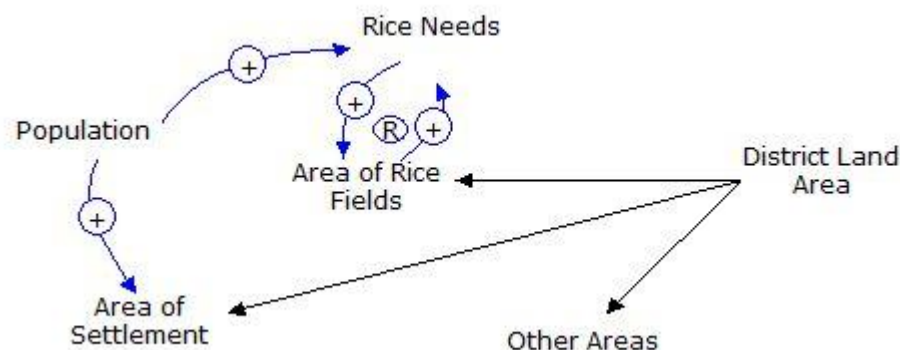

Figure 1. System Dynamics Methodology

The Causal Loop Diagram in Figure 1 above can be interpreted as follows:

The population is directly proportional to the settlement area, so the larger the population, the greater the amount of residential land needed. The population is directly proportional to rice consumption, so the larger the population, the greater the number of rice needs, and the need for rice is directly proportional to the area of rice fields, so the greater the need for rice, the greater the number of rice fields needed. On the other hand, if the area of rice fields increases, the rice needs that can be met will also increase. This causal relationship is then expressed in a synopsis. In this case, the causal relationship is characterized by reinforcement or reinforcement because there are two mutually supportive relationships.

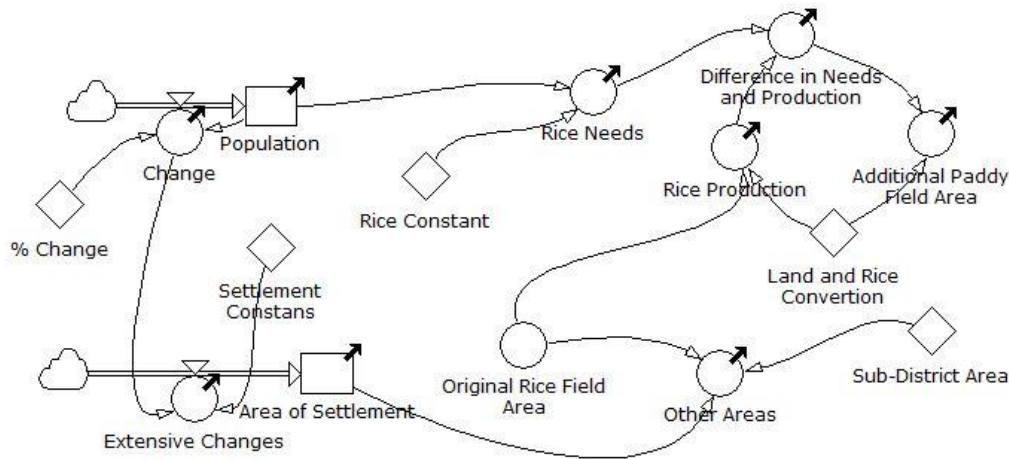If described, the relationship between variables and dynamic systems is as follows.

Figure 2. Dynamic Model of Land Demand Prediction System in Blangkejeren Sub-District

III. RESULT AND DISCUSSION

3.1. Overview of Study Area

Blangkejeren Sub-District is the center of government and the capital of Gayo Lues Regency, Aceh Province, Indonesia. Blangkejeren District has an area of 169.52 Km², consisting of 22 villages and 77 hamlets (the smallest local environmental unit/SLS). BPS data says that the number of residents of Blangkejeren Sub-District in 2023 will be 31,924. According to the spatial map of Gayo Lues Regency, the current area of rice fields is 632 hectares. The rice field area can be seen in Figure 3 below.
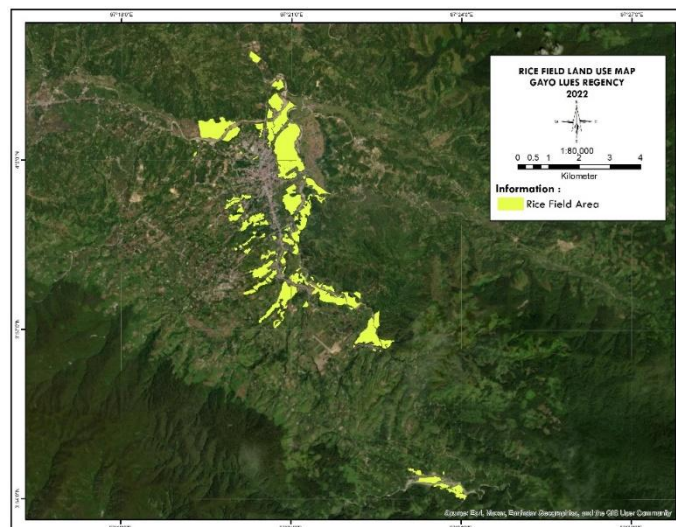

Figure 3. Map of Rice Field Land Use in Blangkejeren District

3.2. Prediction of Rice Field Area per Year

The annual additional rice land area prediction for Blangkejeren Sub-District shows a steadily increasing trend from 2025 to 2045 (see Figure 4). In 2025, the area of rice fields is estimated to be around 1818.64 hectares. These results show a consistent annual increase, with an additional area of rice fields reaching more than 2677.78 hectares by 2045. The increase in the projected area of rice fields reflects efforts to accommodate the increase in rice demand, which is also predicted to increase. Along with population growth and increased demand for rice, expanding rice fields is important to ensure sufficient food availability for the community.
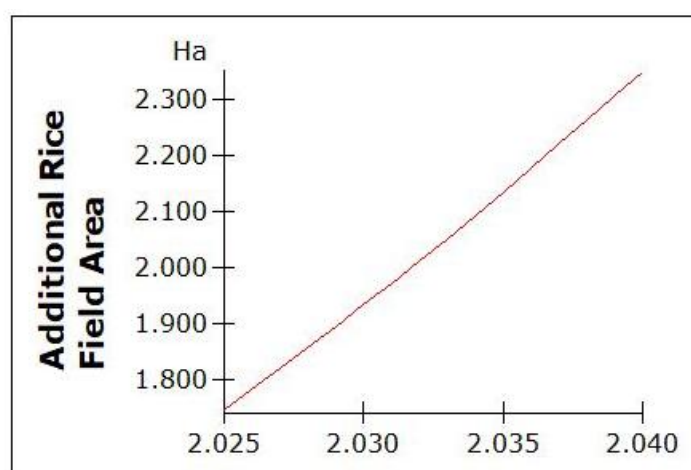

Figure 4. Graph of Increase in Land Demand Prediction

The linear growth in Figure 4 shows that the additional area of rice fields occurs continuously every year. This indicates the need for careful planning in the agricultural sector in Blangkejeren. Efforts to open up new land and increase the productivity of existing land will be key to meeting food needs in the future.

Local governments and stakeholders must work together to develop effective strategies to ensure sufficient and sustainable replenishment of paddy fields. With this clear prediction, Blangkejeren has the opportunity to plan policies that can anticipate and manage the predicted increase in rice field needs, maintain food security, and ensure community welfare. The prediction of the area of rice fields in the future can be seen in Table 1 below.

Table 1. Prediction of Rice Field Area in Blangkejeren District

Year	Population (people)	Change (people)	Additional Rice Field Area (Ha)	Rice Needs (kg)	Difference in Demand and Production (kg)
2025	32852	474	1818.640727	8705780	6114980.641
2026	33326	481	1855.998075	8831390	6240590.641
2027	33807	488	1893.907114	8958855	6368055.641
2028	34295	495	1932.367844	9088175	6497375.641
2029	34790	502	1971.380265	9219350	6628550.641
2030	35292	509	2010.944376	9352380	6761580.641
2031	35801	517	2051.060179	9487265	6896465.641
2032	36318	524	2091.806485	9624270	7033470.641
2033	36842	532	2133.104482	9763130	7172330.641
2034	37374	539	2175.032982	9904110	7313310.641
2035	37913	547	2217.513174	10046945	7456145.641
2036	38460	555	2260.623869	10191900	7601100.641
2037	39015	563	2304.365068	10338975	7748175.641

2038	39578	571	2348.736771	10488170	7897370.641
2039	40149	579	2393.738977	10639485	8048685.641
2040	40728	588	2439.371687	10792920	8202120.641
2041	41316	596	2485.713714	10948740	8357940.641
2042	41912	605	2532.686245	11106680	8515880.641
2043	42517	614	2580.368093	11267005	8676205.641
2044	43131	622	2628.759257	11429715	8838915.641
2045	43753	631	2677.780925	11594545	9003745.641

Source: Analysis Results

Table 1 above illustrates that projections in Blangkejeren District start from 2025 to 2045, and various important trends must be considered in planning and decision-making. The population of Blangkejeren District is expected to increase significantly from 31,924 people in 2023 to 43,753 people in 2045. An increase follows this increase in population in the need for rice fields and rice.

Rice demand shows a significant trend, from 8,705,780 kilograms in 2025 to 11,594,545 kilograms in 2045. The gap between the demand and rice production that continues to increase confirms that the current local rice production is not enough to meet the growing demand. This emphasizes increasing rice production through expanding rice fields and agricultural productivity [15].

The additional area of rice fields needed is also increasing every year, from 1818.64 hectares in 2025 to 2,677.78 hectares in 2045. This indicates that to meet the increasing demand for rice, Blangkejeren District needs to plan to expand agricultural areas sustainably and efficiently[16].

This forecast, related to the increase in the rice field area and the increase in rice demand, provides an overview of the challenges and opportunities that must be faced in realizing sustainable development goals, especially regarding food security and land use [17].

Based on the latest analysis, the change resulting from this prediction indicates an increase in pressure on land that may have previously been used for other activities, such as agriculture. Conversion of agricultural land to non-agricultural land due to population growth and urbanization[18], [19]. This makes it challenging for local food security as less and less land is available for food production[20], [21].

Along with population development, the demand for rice in the Blangkejeren District is projected to increase. In 2025, the demand for rice in this sub-district is estimated to reach 8,705,780 kilograms, and this figure is predicted to increase to 11,594,545 kilograms in 2045. This increase reflects the growing challenge for local governments in ensuring that the community's food needs are met locally [5].

This increase in rice demand shows there will be additional pressure on farmland to produce more rice. However, the agricultural land may decrease with the expansion of settlements expected to continue. Therefore, increasing the productivity of existing land is a very important solution [22] [23].

More efficient and sustainable agricultural technologies are needed to increase productivity [22]. For example, using superior varieties, implementing agricultural intensification, and improving irrigation systems can help increase agricultural yields per hectare so that rice needs can be met without significantly expanding rice fields[6].

IV. CONCLUSION

The study results show that the prediction of agricultural land needs has increased significantly. This increase is in line with the increase in population growth in Blangkejeren Sub-District from 2025 to 2045. On that basis, strategic and sustainable planning and the application of technological efficiency are needed to ensure food security in the future. It is important to achieve SDG 2, as stakeholders are critical in generating regional policies and strategies to support food security. Furthermore, it is also necessary to pay attention in the future to further research to complement this research, such as the theme of land suitability for rice commodities.

REFERENCES

[1]   D. Orden, "Agricultural producer support estimates for developing countries: Measurement issues and evidence from India, Indonesia, China, and Vietnam," *Res. Rep. Int. Food Policy Res. Inst.*, no. 152, pp. 1–140, 2007, [Online]. Available: https://api.elsevier.com/content/abstract/scopus_id/34547125101

[2]   I. Alfiansyah *et al.*, "Reduce the conversion of paddy fields to strengthen food security in Dabun Gelang sub-district," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 1302, no. 1, p. 12079, 2024, doi: 10.1088/1755-1315/1302/1/012079.

[3]   I. Alfiansyah, "Potensi Pengembangan Wilayah di Kabupaten Gayo Lues Provinsi Aceh," *Ekon. J. Ilmu Ekon. dan Stud. Pembang.*, vol. 23, no. 1, pp. 192–200, 2023, doi: 10.30596/ekonomikawan.v23i1.15570.

[4]   R. Alfred, "Towards paddy rice smart farming: A review on big data, machine learning, and rice production tasks," *IEEE Access*, vol. 9. pp. 50358–50380, 2021. doi: 10.1109/ACCESS.2021.3069449.

[5]   S. Peng, Q. Tang, and Y. Zou, "Current status and challenges of rice production in China," *Plant Prod. Sci.*, vol. 12, no. 1, pp. 3–8, 2009, doi: 10.1626/pps.12.3.

[6]   H. Wittman and J. Blesh, "Food Sovereignty and Fome Zero: Connecting Public Food Procurement Programmes to Sustainable Rural Development in Brazil," *J. Agrar. Chang.*, vol. 17, no. 1, pp. 81–105, 2017, doi: 10.1111/joac.12131.

[7]   D. Tilman, C. Balzer, J. Hill, and B. L. Befort, "Global food demand and the sustainable intensification of agriculture," *Proc. Natl. Acad. Sci. U. S. A.*, vol. 108, no. 50, pp. 20260–20264, 2011, doi: 10.1073/pnas.1116437108.

[8]   D. Griggs *et al.*, "Sustainable developmnet goals for people and planet," *Nature*, vol. 495, no. 7441, pp. 305–307, 2013.

[9]   BPS, "angka-konversi-gkp-ke-gkg-dan-gkg-ke-beras," *BPS*, 2018. https://sultra.bps.go.id/statictable/2022/08/14/4023/angka-konversi-gkp-ke-gkg-dan-gkg-ke-beras-2018.html (accessed Aug. 14, 2022).

[10]   A. S. Akopov, "Designing of integrated system-dynamics models for an oil company," *Int. J. Comput. Appl. Technol.*, vol. 45, no. 4, pp. 220–230, 2012, doi: 10.1504/IJCAT.2012.051122.

[11]   C. Caballini, S. Sacone, and S. Siri, "The port as a system of systems: A system dynamics simulation approach," *Proc. - 2012 7th Int. Conf. Syst. Syst. Eng. SoSE 2012*, pp. 191–196, 2012, doi: 10.1109/SYSoSE.2012.6384155.

[12]   R. T. Nguyen and D. D. Imholte, "China's Rare Earth Supply Chain: Illegal Production, and Response to new Cerium Demand," *Jom*, vol. 68, no. 7, pp. 1948–1956, 2016, doi: 10.1007/s11837-016-1894-1.

[13]   A. A. Boyko, V. V. Kukartsev, K. Y. Lobkov, and A. A. Stupina, "Strategic planning toolset for reproduction of machinebuilding engines and equipment," *J. Phys. Conf. Ser.*, vol. 1015, no. 4, 2018, doi: 10.1088/1742-6596/1015/4/042006.

[14]   D. C. Lane, "The emergence and use of diagramming in system dynamics: A critical account," *Syst. Res. Behav. Sci.*, vol. 25, no. 1, pp. 3–23, 2008, doi: 10.1002/sres.826.

[15]   V. H. Smith and J. W. Glauber, "Trade, policy, and food security," *Agric. Econ. (United Kingdom)*, vol. 51, no. 1, pp. 159–171, 2020, doi: 10.1111/agec.12547.

[16]   K. Pawlak and M. Kołodziejczak, "The role of agriculture in ensuring food security in developing countries: Considerations in the context of the problem of sustainable food production," *Sustain.*, vol. 12, no. 13, 2020, doi: 10.3390/su12135488.

[17]   N. Yang, J. Li, B. Lu, M. Luo, and L. Li, "Exploring the spatial pattern and influencing factors of land carrying capacity in Wuhan," *Sustain.*, vol. 11, no. 10, 2019, doi: 10.3390/su11102786.

[18]   T. C. H. Sunderland, "SDG 2: Zero Hunger-Challenging the hegemony of monoculture agriculture for forests and people," *Sustainable Development Goals: Their Impacts on Forests and People*. pp. 48–71, 2019. [Online]. Available: https://api.elsevier.com/content/abstract/scopus_id/85084603955

[19]   T. P. Tuong and B. A. M. Bouman, "Field water mangement to save water and increase its productivity in irrigated lowland rice," *Agric. Water Manag.*, vol. 1615, pp. 1–20, 2000.

[20]   K. Zajícová, "Effect of land use on soil chemical properties after 190 years of forest to agricultural land conversion," *Soil Water Res.*, vol. 14, no. 3, pp. 121–131, 2019, doi: 10.17221/5/2018-SWR.

[21]   V. C. Pham, "The conversion of agricultural land in the peri-urban areas of Hanoi (Vietnam): patterns in space and time," *J. Land Use Sci.*, vol. 10, no. 2, pp. 224–242, 2015, doi: 10.1080/1747423X.2014.884643.

[22]   P. Conceição, S. Levine, M. Lipton, and A. Warren-Rodríguez, "Toward a food secure future: Ensuring food security for sustainable human development in Sub-Saharan Africa," *Food Policy*, vol. 60, pp. 1–9, 2016, doi: 10.1016/j.foodpol.2016.02.003.

[23]   S. Bringezu *et al.*, *Assessing Global Land Use :* 2014.

[24]   K. Madani and M. A. Mariño, "System dynamics analysis for managing Iran's Zayandeh-rud river basin," *Water Resour. Manag.*, vol. 23, no. 11, pp. 2163–2187, 2009, doi: 10.1007/s11269-008-9376-z.