Prediction of rice consumption in South Kalimantan by considering population growth rate

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Abstract. The availability of rice in an area that is less than the requirement of the population might have an impact on the instability of economic. The Province of South Kalimantan is one of the regions in the territory of Indonesia which is one of the mainstays as a source of production of national rice and barns. Population in the province continues to increase from year to year and greatly influences the dynamics of the number of rice consumption in the area. In this study, we predict the rice consumption in the Province of South Kalimantan by considering the population growth rate in the region. Rice production is modeled mathematically by forming assumptions that pay attention to data on harvested area, productivity, and productions of milled dry grain and rice. Parameters that affect the model are estimated by using the nonlinear least squares method. Furthermore, we present predictions of the number of rice production and consumption in the Province of South Kalimantan. From these predictions, it can be concluded that from 2019 to 2028, the Province of South Kalimantan experienced a surplus of rice that continued to increase to exceed 100%, and from 2029 to 2050 it declined to reach 74.02%.

1. Introduction

Food is the main basic need for humans that must be always met. The right to obtain food is one of the human rights. As a basic need and human right, food has meaning and an important role in the life of a nation. The availability of food that is smaller than the people's needs can create economic instability in a country. Various social and political upheavals can occur if food security is disrupted, which in turn can endanger national stability [1]. Fulfilling food requirements for the community is very important and strategic to maintain the sovereignty of the country, where a country is no longer dependent on food imports from developed countries. The dependence of a country on food imports can result in decision-making in all aspects of life to be not free, and because of this, the state can become completely sovereign [2].

Demand for food, especially rice, which is inelastic normally, implies that price fluctuations will not result in large changes in demand. Demand tends to be constant over time. In the long run, the demand continues to increase because the population growth rate is also increasing. Meanwhile, food availability is fraught with uncertainty. This encourages the government to intervene by realizing food security policies [1]. In realizing food security, to reduce rice consumption and simultaneously increase consumption of food other than rice, the government has implemented a food diversification program. If the problem of domestic rice scarcity occurs, the government will anticipate this by increasing reserves in areas that have the potential to produce rice or import rice from outside.

The existence of a food barn plays a very important role in supporting the availability of food in an area. Food storage is a food reserve for the community. When the harvest fails due to pests or natural

disasters, the food needs are met with the food reserves in the barn. When there is excess production during the main harvest season, farmers can regulate supply by storing their harvest in the barn [3].

One of the provinces that have become a national food storage area is the province of South Kalimantan. This region always tries to maintain this status by increasing the food production of rice, maize, and secondary crops. The Head of the Food Crops and Horticulture Service of South Kalimantan said that the production of food crops and horticulture in South Kalimantan in the last two years, namely 2015-2017 has increased sharply. There was an increase in rice production by 275,010 tons of Dry Unhusked Rice (DUR), or an increase of around 12.85% of total production, which was 2,140,276 tons of DUR in 2015 to 2,415,286 ton of DUR in 2017. The increase in rice production was supported by an increase in planted areas [4].

Apart from the aforementioned problems, many changes in the function of agricultural land to new settlements in various areas in South Kalimantan Province continue to occur. It cannot be denied that every year the population is increasing. For example, in the period 2016 - 2017, the conversion of agricultural land in Banjar Regency reached nearly ten thousand hectares [5]. The number of rice fields in the area in 2016 was 68,645 hectares. Meanwhile, in 2017, the number of paddy fields decreased to 59,551 hectares.

Rice consumption is influenced by the people's behavior in consuming rice in a consumer subsystem. Submodels of consumption can be seen from the dynamics of population development, which affects the demand for rice consumption [6]. The balance between rice availability and consumption needs is strongly influenced by population. If an area has rice availability that is greater than the rice consumption needs of the entire population, then that region is said to be a rice surplus. Meanwhile, if an area has rice availability that is smaller than the rice consumption needs of the entire population, then that region is said to be a rice deficit.

Based on this, this paper examines the prediction of rice consumption of the population in South Kalimantan Province. Researchers consider the population growth rate of South Kalimantan which has been studied by Karim and Yulida (2019) [. The results of this prediction provide an overview of the total demand for rice from the population and the rice surplus/deficit that will occur in the coming years in South Kalimantan Province. This prediction can also be used as a basis for decision-making parties in formulating efforts to ensure the availability of rice for the population in the coming years, as well as an effort to support national food security.

2. Materials and Methods

This research was conducted in several stages, namely conducting studies and literature review, as well as finding information on population data and information on rice production in South Kalimantan Province. In this study, the predictive data for the population of South Kalimantan used were the results of a study by Karim and Yulida in 2019 [7]. The study produces parameters of population growth rate and population capacity in Prov. South Kalimantan, namely 0.14055 people per year and 8,521,818 people, respectively.

Data on harvested area, productivity, and production of DUR rice in 2003-2015 were obtained from the Central Statistics Agency of South Kalimantan, while in 2016-2018 it was obtained from the Food Crops and Horticulture Service of South Kalimantan.

Furthermore, the first step in this research is to determine the solution to the logistic growth model [8] [9][10] using separate differential equations [11][12][13]. The second step is to calculate the number of rice production (ton). As information that will be used for this calculation is, South Kalimantan Province has a conversion rate of milled dry grain to rice of 65.69% [14] Thus, the number of rice production (ton) can be calculated using the following formula:

$$\text{rice production (ton)} = 65.69\% \times \text{production of DUR (ton)} \quad (1)$$

In the third step, we estimate the parameters of the growth rate of rice production and at the same time estimate the parameters of the carrying capacity of rice production in South Kalimantan, by minimizing the errors between rice production data and the Logistics growth model solutions using the nonlinear least squares method. The nonlinear least-squares problem is to minimize the following functions:

$$\sum_{i=0}^{m} r_i(x)^2 = \|r(x)\|^2 \quad (2)$$

where r_i is a nonlinear function, x is a variable of n dimension, and the vector function $r: \mathbb{R}^n \to \mathbb{R}^m$, $m \geq n$, $r(x) = (r_1(x), r_2(x), \dots, r_m(x))$. The minimum value can be determined via common optimization methods [15,16]

In the fourth step, we determine the prediction of rice production in South Kalimantan (ton) in the next few years. In the fifth step, we calculate the number of rice consumption per year using population data and assume that the per capita rice consumption of the population in South Kalimantan is 114 kg/capita/year. The final step is, we predict rice consumption and rice surpluses in South Kalimantan Province for the next few years.

3. Results and Discussion

3.1. Parameter Estimation

We assume that the growth in total rice production follows the logistical growth model. This is because the number of rice production is limited to the area of rice fields in South Kalimantan. Based on the logistical growth model, we form a rice production growth model as follows:

$$\frac{dP(t)}{dt} = \mu\, P(t)\left(1 - \frac{P(t)}{C}\right) \quad (3)$$

Equation (3) is a first-order differential equation that can be separated, namely:

$$\frac{dP(t)}{P(t)\left(1-\frac{P(t)}{C}\right)} = \mu\, dt \quad (4)$$

Equation (4) is solved by integrating the two sides so that the solution of Equation (3) is obtained as follows:

$$P(t) = P_t = \frac{C}{1+\left(\frac{C}{P_0}-1\right)e^{-\mu t}} \quad (5)$$

with P_t is the number of rice production at time t (which is the solution to the logistical growth model), μ is the growth rate of rice production, and C is the carrying capacity of rice production.

Next, we estimate the parameters on the values that affect the growth model of rice production in Equation (5), namely: rice production growth rate (μ) and rice production carrying capacity (C), using the non-linear least square method.

Based on the non-linear least square method, we form the Error function, which states the difference between the predicted results of rice production (the logistic growth model solution in Equation (5)) and the actual rice production data (data from BPS and the Food Crops and Horticulture Service of Kalimantan Province. South). Then, the function is squared and we form an error function, namely the sum of squares by using the non-linear least square method referring to Equation (2). Its function can be expressed as a problem of minimizing,

$$e = \sum_{t=1}^{16}\left(P_t - P_{data\_t}\right)^2 \quad (6)$$

where P_t is the data from the prediction of rice production at time t, which is a solution to the logistic growth model with the time used is $t = 1,2,\dots,16$. This is because the available data are from 2003-2018.

Next, we provide Table 1, which is the calculation result of rice production in South Kalimantan Province. These results were calculated using survey data from BPS (2018), with the conversion rate of DUR to rice of 65.69%.

Table 1. Harvested area, productivity, and rice production in South Kalimantan

Year	Harvested Area (ha)	Productivity (quintal/ha)	DUR Rice Production (ton)	Rice Production (ton)
2003	438487	32.16	1410174.19	926343.43
2004	443508	34.26	1519458.41	998132.23
2005	459541	34.79	1598743.14	1050214.37
2006	462672	35.38	1636933.54	1075301.64
2007	505846	38.63	1954083.10	1283637.19
2008	507319	38.52	1954192.79	1283709.24
2009	490069	39.93	1956845.52	1285451.82
2010	471166	39.10	1842259.06	1210179.98
2011	489134	41.67	2038221.38	1338907.62
2012	496082	42.05	2086024.81	1370309.70
2013	479721	42.34	2031138.71	1334255.02
2014	498133	42.05	2094649.27	1375975.10
2015	511213	41.87	2140448.83	1406060.84
2016	547449	42.26	2313519.47	1519750.94
2017	569993	43.02	2452109.89	1610790.98
2018	594827	41.03	2440575.18	1603213.84

Based on Equation (6) and Table 1, we compile an optimization program, which aims to predict the number of rice production in South Kalimantan Province in the next few years. We estimate the parameters that affect the model, then curve fitting based on these parameters. The number of rice production in South Kalimantan Province in 2003-2018 can be shown in Figure 1.

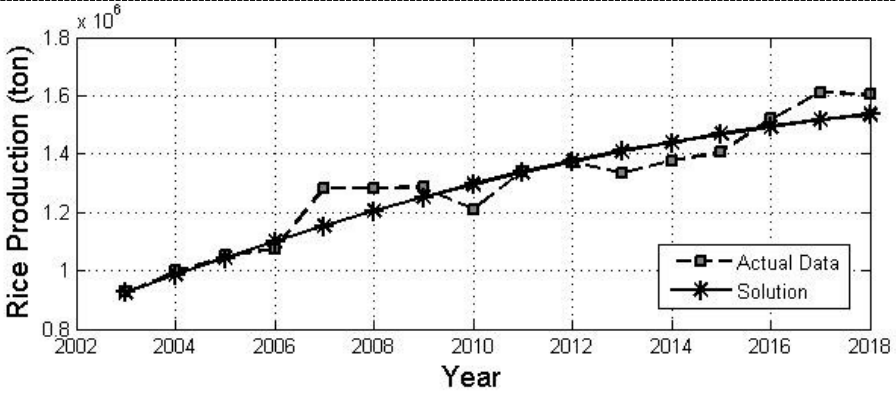

Figure 1. Graph of the Rice Production in South Kalimantan in 2003-2018

The dotted lines graph the number of rice production (actual data), while the smooth lines graph the solutions of the Model (5). The results of the optimization carried out resulted in parameters for the growth rate of rice production and the parameters for the capacity of rice production in South Kalimantan Province as given in Table 2 below.

Table 2. Estimated results of the growth rate and carrying capacity of rice production in South Kalimantan

Hasil Estimasi	Nilai
The growth rate of rice production	$\mu = 0.14498$ per year
Carrying capacity of rice production	$C = 1677766.322$ ton

3.2. Prediction of Total Consumption and Surplus of Rice in South Kalimantan

The prediction of the growth rate of rice production in South Kalimantan using the optimization result parameter in Table 2 is 0.14498 per year, while the carrying capacity of rice production in South Kalimantan is 48016.77 ton of rice. If these two parameters are substituted for the solution to the rice production growth model in Equation (5), then the prediction graph of Rice Production in South Kalimantan in 2019-2050 is obtained as follows (Figure 2).

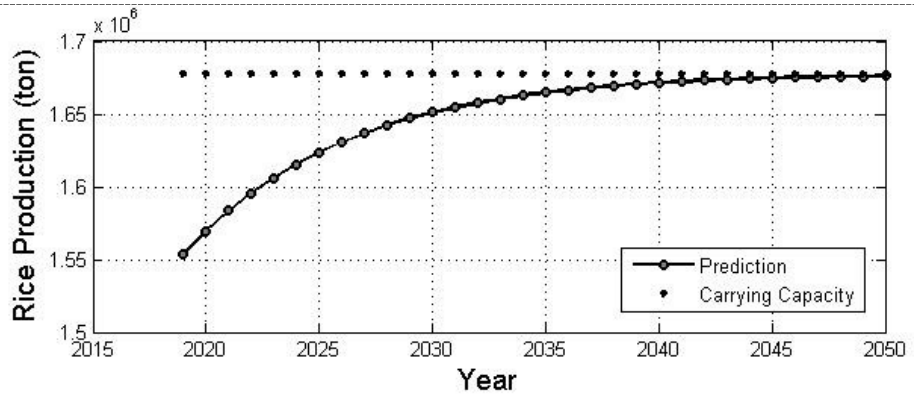

Figure 2. Graph of Prediction of Rice Production in South Kalimantan in 2019-2050

Furthermore, a prediction of rice consumption in South Kalimantan is given in 2019-2050. Based on the DTPH of South Kalimantan Province, the assumption of rice demand in this province in 2018 is 114 kg/capita/year. The number of rice consumption (ton) in the observed year is equivalent to the multiplication of the predicted value of the population in the observed year with the rice demand of 114 kg/capita/year. Then, the rice surplus (ton) is equivalent to the difference between the number of rice production and rice consumption in the observed year. Meanwhile, the surplus-value (percent) is equivalent to one hundred times the ratio between rice surplus (ton) and rice consumption (ton). The results of these calculations, using the assumption of rice consumption per capita of the population in South Kalimantan of 114 kg/capita/year are presented in Table 3 below.

Table 3. Prediction of rice consumption and rice surplus in South Kalimantan

Year	Prediction of rice production ()	Prediction of population (people)	Prediction of rice consumption (ton)	Prediction of rice surplus (ton)	Prediction of Surplus (percent)
2019	1553963.4039	5113836	582977.2529	970986.1510	166.56
2020	1569608.9163	5396887	615245.0812	954363.8351	155.12
2021	1583374.2100	5669549	646328.5957	937045.6142	144.98
2022	1595463.6795	5929776	675994.4378	919469.2417	136.02
2023	1606086.4199	6176098	704075.1453	902011.2746	128.11
2024	1615421.1224	6407393	730442.8284	884978.2940	121.16
2025	1623591.8182	6622909	755011.5886	868580.2297	115.04
2026	1630716.7243	6822259	777737.5179	852979.2063	109.67
2027	1636912.1187	7005427	798618.6998	838293.4190	104.97

2028	1642292.3413	7172764	817695.0762	824597.2651	100.84
2029	1646969.7931	7324876	835035.9073	811933.8857	97.23
2030	1651053.8295	7462445	850718.7704	800335.0590	94.08
2031	1654620.1980	7586239	864831.2469	789788.9512	91.32
2032	1657719.8981	7697113	877470.8526	780249.0455	88.92
2033	1660404.3664	7796009	888745.0380	771659.3284	86.83
2034	1662723.9231	7883958	898771.1879	763952.7352	85.00
2035	1664727.7725	7962072	907676.1808	757051.5917	83.41
2036	1666464.0025	8031353	915574.2818	750889.7207	82.01
2037	1667978.3726	8092572	922553.2515	745425.1211	80.80
2038	1669297.5069	8146475	928698.1937	740599.3132	79.75
2039	1670440.6643	8193801	934093.3629	736347.3014	78.83
2040	1671427.8929	8235282	938822.1651	732605.7278	78.03
2041	1672278.7948	8271642	942967.1570	729311.6378	77.34
2042	1673012.5267	8303587	946608.9574	726403.5693	76.74
2043	1673647.7993	8331636	949806.5426	723841.2567	76.21
2044	1674202.0126	8356170	952603.3895	721598.6231	75.75
2045	1674684.1099	8377563	955042.1798	719641.9301	75.35
2046	1675101.3324	8396180	957164.5094	717936.8230	75.01
2047	1675461.2040	8412376	959010.8885	716450.3155	74.71
2048	1675771.0815	8426498	960620.7419	715150.3396	74.45
2049	1676038.1544	8438869	962031.0890	714007.0654	74.22
2050	1676269.4446	8449688	963264.4698	713004.9748	74.02

Based on Table 3, the following Figure 3 is a prediction curve for rice consumption (ton) in South Kalimantan in 2019-2050.

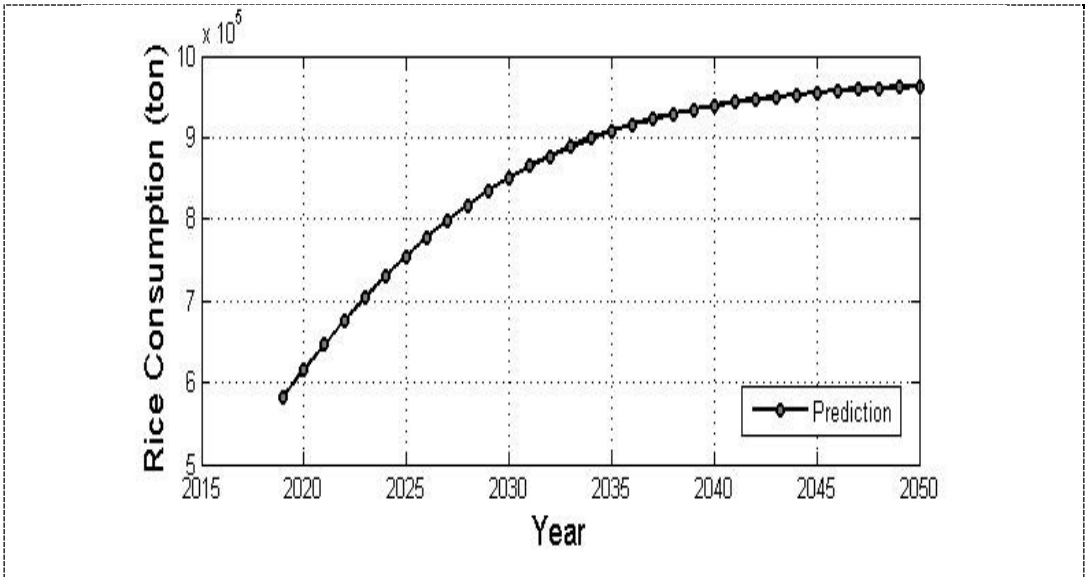

Figure 3. Graph of the Rice Consumption Prediction in South Kalimantan 2019-2050

Figure 3 shows that rice consumption in South Kalimantan will continue to increase. This is consistent with the prediction that the population of South Kalimantan will continue to increase (Figure 1). Increasing rice consumption is the effect of positive population growth. Furthermore, based on Table 3, the following (Figure 4) also presents a graph of the prediction of rice surplus (percent) in South Kalimantan in 2019-2050.

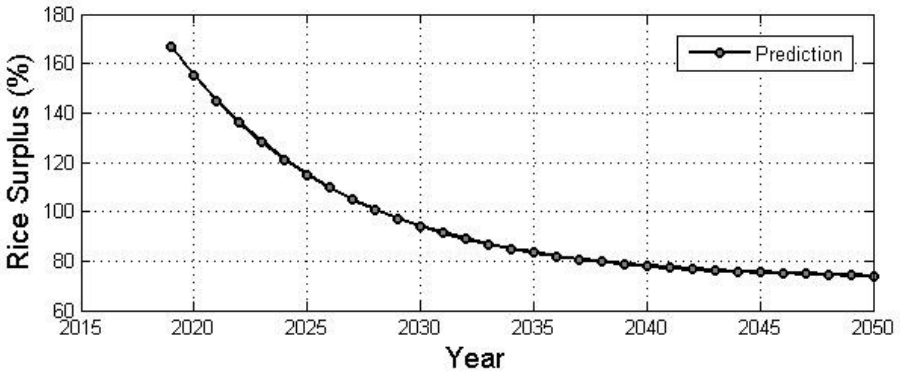

Figure 4. Graph of the Rice Surplus Prediction in South Kalimantan, 2019-2050

From Figure 4, in the future prediction from 2019 to 2028, rice production surplus in South Kalimantan Province could reach 100%. This pattern means that, if there is a crop failure in the following year (in the range of 2019-2028), the rice supply can still meet the rice demand of the entire population in South Kalimantan. In the period 2028-2050, the rice surplus is predicted to decline to reach 74.02%. Based on this analysis, the rice supply in South Kalimantan Province is still very good and this shows that the level of food security in this province is quite high.

4. Conclusion

From this paper, it is produced the growth rate and carrying capacity of rice production in South Kalimantan were 0.14498 per year and 1,677,766.322 tons of rice, respectively. Based on these two values, the number of rice production in South Kalimantan in 2019-2050 is predicted to continue to increase until it reaches its carrying capacity. In addition, South Kalimantan Province is predicted to experience a rice surplus, with a surplus reaching 100% in 2019-2028 and decreasing to 74.02% in 2029-2050.

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References

[1] Ismet M 2007 Tantangan Mewujudkan Kebijakan Pangan yang Kuat Pangan XVI 48 3-9

[2] Arifin B 2004 Analisis Ekonomi Pertanian Indonesia (Jakarta: Penerbit Buku Kompas)

[3] Purwaningsih Y 2008 Ketahanan Pangan: Situasi, Permasalahan, Kebijakan, Dan Pemberdayaan Masyarakat Jurnal Ekonomi Pembangunan 9 (1)1-27

[4] Mediaindonesia.com 2018 Produksi Pangan Kalsel Terus Meningkat (https://mediaindonesia.com/nusantara/140836/produksi-pangan-kalsel-terus-meningkat)

[5] Jejakrekam.com 2018 10 Ribu Hekatre Sawah Kabupaten Banjar Berubah Jadi Komplek Perumahan (http://jejakrekam.com/2018/03/12/10-ribu-hektare-sawah-kabupaten-banjar-berubah-jadi-komplek-perumahan)

[6] Mahbubi A 2013 Model Dinamis Supply Chain Beras Berkelanjutan Dalam Upaya Ketahanan Pangan Nasional Jurnal Manajemen & Agribisnis **10** 81-89

[7] Karim M A and Yulida Y 2019 Prediksi Jumlah Penduduk Kalimantan Selatan Menggunakan Metode Nonlinear Least-Squares Media Bina Ilmiah **14** 2605-2609.

[8] Eberhardt and Breiwick 2012 Model for Population Growth Curves *International Scholarly Research Network ISRN Ecology* 1-8.

[9] Tsoularis A 2001 Analysis of Logistic Growth Models *Res. Lett. Inf. Math. Sci* **2** 23-46

[10] Barnes B and Fulford G R 2002 *Mathematical Modelling with Case Studies* (London and New York: Taylor and Francis)

[11] Ross S L 2004 *Differential Equation Third Edition* (New Delhi: John Wiley & Sons)

[12] Alwash M 2017 *Ordinary Differential Equations: A First Course* (Los Angeles: Spring)

[13] Yulida Y 2019 *Persamaan Diferensial Biasa* (Malang: CV IRDH)

[14] BPS 2018 *Konversi Gabah ke Beras Tahun 2018* (Jakarta: PT Citra Mawana Patamaro)

[15] Madsen K, Nielsen H B, and Tingleff O 2004 *Methods for Non-Linear Least Squares Problems 2nd Edition* (Denmark: Informatics and Mathematical Modelling)

[16] Karim M A, Gunawan A Y, Apri M, and Sidarto K A 2018 Solving a Parameter Estimation Problem of Goodwin Model with Fuzzy Initial Values *Far East Journal of Mathematical Sciences* **107** 321-38.