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Numerical Analysis of Rice Growth Phases in Karawang using the Gauss-Jordan Elimination Method

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Abstract

Indonesia's growth cannot be separated from Indonesia's economic growth. The agricultural sector has a massive and significant impact on Indonesia's economic growth. One of the agricultural products that's important is rice. Rice is a seasonal crop that is very necessary for human survival. Karawang, one of the districts in West Java Province, which is known as Lumbung Padi City, is the location of the main topic in making this journal. In fact, based on BPS data, the area harvested for paddy fields in Karawang from 2010-2015 was found not to have increased regularly from year to year. This is interesting to discuss because the rice harvest area is expected to increase regularly to support Indonesia's economic growth. Of course, this is because the rice harvest area will affect the amount of rice produced in the rice fields. By ignoring other internal and external factors of rice growth, this journal will only focus on rice harvest area based on rice growth phases (vegetative 1, vegetative 2, and generative) and accumulated harvest area using the Gauss Jordan elimination method. Calculations are carried out to determine the possibility of farmers to predict the maximum amount of rice production and avoid losses in purchasing materials to support rice growth

Keywords: rice growth phases, Gauss Jordan Elimination Method, Rice Harvest Area, Vegetative Phase, Generative Phase

1. Introduction

Indonesia's overall growth can never be separated from the economic growth of each region in Indonesia. One of the cities that has currently attracted our attention to highlight is Karawang. Karawang is interesting to review because of a journal that discusses rice growth phases as one of the factors that influence changes in area. After reading the main journal, namely "Area Sampling Frame Approach for Estimating and Forecasting Rice Production" created by Mubekti and Lena Sumargana (Sumargana, 2016) and supported by BPS data, an interesting thing that was found was that rice production in Karawang tends to change.

Based on the BPS data that has been obtained, the data states that the area harvested for paddy fields in 2010 was around 184,627 hectares. The rice harvest area in 2011 was around 186,366 hectares. The rice harvest area in 2012 was around 182,863 hectares. The rice harvest area in 2013 was around 185,052 hectares. The rice harvest area in 2014 was around 186,874 hectares.

The rice harvest area in 2015 was around 183,136 hectares. The rice harvest area in 2016 was around 186,984 hectares. Based on these data, rice production results mean that the harvested area has not seen a regular increase from year to year. Thus, the area of rice harvested in a rice field will of course affect the rice production results in that rice field.

It cannot be denied that lowland rice production results can change a lot due to various factors that influence the rice growth phase. This can happen because rice growth is actually caused by several factors, there are internal factors and also external factors. Internal factors in rice growth include the quality of rice seeds, the age of the rice plant, the physical form of the rice plant, the capacity to store food reserves and the plant's resistance to disease (Gardner, 1991).

Meanwhile, according to Ai and Torey, external factors for rice growth are sunlight, water, humidity and soil temperature, rainfall, soil type and use of fertilizer (Pramono, 2020). Apart from natural factors in rice fields, there are also stages of rice growth phases. The reason why the rice growth phase is a significant change factor in the rice crop production of the Karawang rice fields is because rice is a seasonal crop that is much needed in society. Therefore, a smooth rice planting process is necessary and necessary for farmers to know maximum production.

However, to shorten the discussion of the paper, it will only be about the topic of discussion, namely "Numerical Analysis of Rice Growth Phases in Karawang using the Gauss-Jordan Elimination Method". Thus, the focus of the discussion is only made around the rice growth phases (vegetative 1, vegetative 2, and generative) and the Gauss-Jordan elimination method.

With the formulation of the problem as follows: (1) BHow many hectares of rice production will be produced if planting is only done once? (2)How many hectares of rice production will be if planting is carried out twice in a span of phases? (3)How many hectares of rice production will be if planting is carried out 3 times in a range of phases? (4)Which conditions are most beneficial for farmers in Karawang to produce maximum rice production?

2. Methods

The rapid rice growth cycle requires correct and fast decisions in overcoming existing problems. For example, export or import of rice, distribution of seeds, fertilizers and pesticides. Biased data and long delivery times for data processing results will cause late decision making. Inaccurate forecasting can make the losses experienced by farmers even greater. The rice predictions taken can be based on the rice planting period.

As stated in the background, rice is a seasonal crop with a short growth period. Starting from the process of planting rice seeds to harvest, it usually only takes approximately 4 months. However, in its growth, rice has three stages of growth phases. The three rice growth phases referred to are the early vegetative growth phase (V_1), late vegetative (V_2), and the generative phase (G). This rice growth phase was created based on IRRI's explanation of value change detection backscatter and characteristics of images that have been composited on Sentinel-1a Time *series* (Leni Suspidayanti, 2021)

Fase V_1 This is the initial phase of growth until panicle formation with a duration of approximately 35 days. For phase V_2 This is the phase from panicle formation to removal, the duration of which is approximately 15 days. Meanwhile, the G phase is the ripening phase where the grain is removed until the grain is mature with a duration of approximately 65 days. Simply put, it can be concluded that vegetative phase 1 is called the vegetative phase, vegetative phase 2 is called the reproductive phase, and the generative phase is called the maturation phase.

For more details, each rice growth phase has a specific growth process, including the following: In the vegetative phase there is a process seedling (planting seeds in rice fields), tillering process (seedlings start to grow and leaves start to grow), and processing stem *elongation* (The height of the rice has changed and the leaves are starting to close). Meanwhile, in the reproductive phase there is a process panicle (rice has started to fill), *heading* (the panicles have started to come out), *flowering* (the panicle has turned into a flower). Then in the final phase, namely the maturation phase, there is a process of milk *grain* (rice grains begin to contain milk), *dough grain* (rice grains begin to harden), and *mature grain* (cooking of grain until harvest) (Leni Suspidayanti, 2021). Based on the three phases of rice growth, a conclusion was found, namely that planting carried out not simultaneously or at the same time allows for abundant harvests. This clearly provides a difference between the rice planting process in ancient times and today. In ancient times, rice planting was only done in certain months or times. So now, farmers can plant rice in stages. This can be done because if a rice field has entered phase V_2 then farmers will replant new rice. So that within a certain time three phases of rice can be implemented and rice production can be guaranteed to be abundant.

In these conditions and situations, we can use mathematics as an approach when forecasting rice production. The mathematical science used is data processing with a system of linear equations using the Gauss-Jordan Elimination Method. The Gauss-Jordan Elimination Method is possible because the process is simple and relatively short. Apart from that, the process of modeling and changing the form of a story problem into a mathematical model in a system of linear equations will make it easier for researchers to look for possible solutions to the problem they are looking for. However, the application of the solution calculation for the Gauss Jordan Elimination Method is actually obtained from modeling a system of linear equations which is converted into a matrix and operating on the row matrix so that it becomes an identity matrix to get the results. Jordan's Gauss Elimination Method has slight differences with the Gauss Elimination Method.

Both the work on the Gauss Elimination Method and the Gauss Jordan Elimination Method both originate from complex statements or the sum of more than two equations to form a System of Linear Equations (Khoirul Anam, 2019). However, the difference between the two is that the row matrix operation is changed because the Gauss Jordan Elimination Method needs to be changed to an identity matrix. Thus there are several general procedures for the Gauss-Jordan Elimination Method, namely:

1. Converts the system of linear equations you want to calculate into an augmented matrix.

$$x + 3y - 2z = 5$$
$$3x + 5y + 6z = 7$$
$$2x + 4y + 3z = 8$$

2. Next, the augmented matrix is converted into an identity matrix.

$$\begin{bmatrix} a_{11} & a_{12} & a_{13} & \cdots & a_{1n} & b_1 \\ a_{21} & a_{22} & a_{22} & \cdots & a_{2n} & b_2 \\ a_{11} & a_{11} & a_{11} & \cdots & a_{3n} & b_3 \\ \vdots & & & & & \vdots \\ a_{n1} & a_{n2} & a_{n3} & \cdots & a_{nn} & b_n \end{bmatrix} \rightarrow \begin{bmatrix} 1 & 0 & 0 & \cdots & 0 & b_1' \\ 0 & 1 & 0 & \cdots & 0 & b_2' \\ 0 & 0 & 1 & \cdots & 0 & b_3' \\ \vdots & & & & & \vdots \\ 0 & 0 & 0 & \cdots & 1 & b_n' \end{bmatrix}$$

The solution: $x_1 = b_1',\ x_2 = b_2', \cdots\ x_n = b_n'$

3. During the process of converting to an identity matrix, the calculation of row operations is adjusted to the desired identity matrix, after which the identity matrix form a11 b22 c33 is the result of completing the desired matrix.

The changes are made by creating a matrix whose elements are the coefficients of a system of linear equations. Meanwhile, the steps in elementary row operations are:

(a) Swap the positions of the 2 rows $A_1 \leftrightarrow A_2$
(b) Multiplies a row by a positive scalar number. $A_1 = k * A_2$
(c) Add a row with a scalar product with another row $A_1 = A_1 + k * A_2$

Example

$$\left[\begin{array}{ccc|c} 1 & 3 & -2 & 5 \\ 3 & 5 & 6 & 7 \\ 2 & 4 & 3 & 8 \end{array}\right]$$

$$\begin{matrix} R_2 - 3R_1 \\ R_3 - 2R_1 \end{matrix} \rightarrow \left[\begin{array}{ccc|c} 1 & 3 & -2 & 5 \\ 0 & -4 & 12 & -8 \\ 0 & -2 & 7 & -2 \end{array}\right]$$

$$-\frac{1}{4}R_2 \rightarrow \left[\begin{array}{ccc|c} 1 & 3 & -2 & 5 \\ 0 & 1 & -3 & 2 \\ 0 & -2 & 7 & -2 \end{array}\right]$$

$$\begin{matrix} R_1 - 3R_2 \\ R_3 + 2R_2 \end{matrix} \rightarrow \left[\begin{array}{ccc|c} 1 & 0 & 7 & -1 \\ 0 & 1 & -3 & 2 \\ 0 & 0 & 1 & 2 \end{array}\right]$$

$$\begin{matrix} R_1 - 7R_3 \\ R_2 + 3R_3 \end{matrix} \rightarrow \left[\begin{array}{ccc|c} 1 & 0 & 0 & -15 \\ 0 & 1 & 0 & 8 \\ 0 & 0 & 1 & 2 \end{array}\right]$$

So, it can be seen that $x = -15, y = 8, z = 2$

The main point or essence of Gauss Jordan elimination is that the researcher or observer can find out the possibility if only one variable is working and the other variables are ignored or eliminated (in mathematics it is called zeroed or eliminated). So by using this method it is possible that we can predict the amount of rice production. With this calculation, we can avoid losses in purchasing materials to support rice growth and focus on other things that are priorities.

3. Result and Discussion

The observation table is taken from the journal (Mubekti, 2016). From the table we will observe 3 data (variables) from 3 surveys. The data that we used are the Rice Harvest Area based on the Rice Growing Phase with Accumulation Rice Harvest Area.

Table 1

Estimated Results of Rice Crop Forecasting in Kabupaten Karawang

Data Umum	Satuan	Survei-1	Survei-2	Survei-3
Jumlah Kiriman Data	segmen	51	51	49
Jumlah Segmen	segmen	51	51	51
Luas Kerangka Sampel Area	hektar	27.225	27.225	127.225
Estimasi Luasan Saat Survei				
Luas Persiapan Lahan (PL)	hektar	28.538	26.543	2.389
Luas Padi Vegetatif-1 (V1)	hektar	20.755	23.449	29.392
Luas Padi Vegetatif-2 (V2)	hektar	15.566	19.258	18.798
Luas Padi Generatif (G)	hektar	18.660	12.112	20.044
Luas Panen Antara 2 Survei	hektar	0	1.662	0
Luas Panen Pada Saat Survei	hektar	19.358	17.528	17.344
Luas Lahan Bera	hektar	0	1.168	14.436
Lain-lain *)	hektar	24.347	25.505	24.822
Total Sawah	hektar	102.878	100.058	102.403
Luas Panen Kumulatif	hektar	19.358	19.191	17.344
Peramalan Luasan dan Produksi				
Luas panen 2 Bulan Kedepan	hektar	34.226	31.370	38.843
Luas panen 4 Bulan Kedepan	hektar	83.519	81.362	70.623
Produksi 2 Bulan Kedepan	ton	343.499	314.836	389.832
Produksi 4 Bulan Kedepan	ton	838.218	816.565	708.785
Akurasi Estimasi				
Koefisien Variasi (CV)	%	4,25	4,95	4,52

*) Lain-lain: lahan bukan sawah atau sawah yang ditanami bukan padi

To make things easier, you can see the following table:

	Survey-1	Survey-2	Survey-3
Vegetative Rice Area-1 (V1)	20755	13449	29392

Vegetative Rice Area-2 (V2)	15566	19258	18798
Generative Rice Area (G)	18660	12112	20044
Accumulation Area	19358	19191	17344

Then it can be converted into a matrix

$$\left(\begin{array}{ccc|c} 20755 & 15566 & 18660 & 19358 \\ 13449 & 19258 & 12112 & 19191 \\ 29392 & 18798 & 20044 & 17344 \end{array}\right)$$

The next step is to reduce the matrix in each row

$$B_1 = \frac{B_1}{20755} \rightarrow \left(\begin{array}{ccc|c} 1 & \frac{15566}{20755} & \frac{3732}{4151} & \frac{19358}{20755} \\ 13449 & 19258 & 12112 & 19191 \\ 29392 & 18798 & 20044 & 17344 \end{array}\right)$$

$$\begin{array}{l} B_2 = B_2 - 13449B_1 \\ B_3 = B_3 - 29392B_1 \end{array} \rightarrow \left(\begin{array}{ccc|c} 1 & \frac{15566}{20755} & \frac{3732}{4151} & \frac{19358}{20755} \\ 0 & \frac{190352656}{20755} & \frac{85244}{4151} & \frac{137963463}{20755} \\ 0 & -\frac{67363382}{20755} & -\frac{26488300}{4151} & -\frac{208995616}{20755} \end{array}\right)$$

$$B_2 = \frac{B_2}{\frac{190352656}{20755}} \rightarrow \left(\begin{array}{ccc|c} 1 & \frac{15566}{20755} & \frac{3732}{4151} & \frac{19358}{20755} \\ 0 & 1 & \frac{106555}{47588164} & \frac{137963463}{190352656} \\ 0 & -\frac{67363382}{20755} & -\frac{26488300}{4151} & -\frac{208995616}{20755} \end{array}\right)$$

$$\begin{array}{l} B_1 = B_1 - \frac{15566}{20755}B_2 \\ B_3 = B_3 + \frac{67363382}{20755}B_2 \end{array} \rightarrow \left(\begin{array}{ccc|c} 1 & 0 & \frac{21352361}{23794082} & \frac{37034629}{95176328} \\ 0 & 1 & \frac{106555}{47588164} & \frac{137963463}{190352656} \\ 0 & 0 & -\frac{151661525349}{23794082} & -\frac{381114814223052 9}{493846171910} \end{array}\right)$$

$$B_3 = \frac{B_3}{-\frac{151661525349}{23794082}} \rightarrow \left(\begin{array}{ccc|c} 1 & 0 & \frac{21352361}{23794082} & \frac{37034629}{95176328} \\ 0 & 1 & \frac{106555}{47588164} & \frac{137963463}{190352656} \\ 0 & 0 & 1 & \frac{1270382714076843}{1049244986206165} \end{array}\right)$$

$$\begin{array}{l} B_1 = B_1 - \frac{21352361}{23794082}B_3 \\ B_2 = B_2 - \frac{106555}{47588164}B_3 \end{array} \rightarrow \left(\begin{array}{ccc|c} 1 & 0 & 0 & -\frac{3924852782248031}{5627866033620491} \\ 0 & 1 & 0 & \frac{4876437104822984 0}{6753439240344589} \\ 0 & 0 & 1 & \frac{1270382714076843}{1049244986206165} \end{array}\right)$$

$$\begin{cases} x_1 = -\dfrac{3924852782248031}{5627866033620491} = 0{,}697396270416038\ hektar \\ x_2 = \dfrac{48764371048229840}{6753439240344589} = 0{,}722067221052568\,1\ hektar \\ x_3 = \dfrac{1270382714076843}{1049244986206165} = 1{,}210758908336806\ hektar \end{cases}$$

From the calculation results obtained

$$\begin{cases} x_1 = -0{,}697396270416038\ hektar = 6.973{,}96270416038\ m^2 \\ x_2 = 0{,}7220672210525681\ hektar = 7.220{,}672210525681\ m^2 \\ x_3 = 1{,}210758908336806\ hektar = 1.2107{,}58908336806\ m^2 \end{cases}$$

So, based on the calculation results, conclusions can be drawn

- If farmers only plant rice in one phase, the harvest they get will only be around one hectare or more precisely around $12.107{,}58908336806\ m^2$

- From the first rice that planed x_1 has entered phase two and farmers are planting rice again x_2 (so there is old rice x_1 and new rice x_2) then production results can be calculated by adding x_1 and x_2 until found

$$x_1 + x_2 = 12.107{,}58908336806\ m^2 + 7.220{,}672210525681\ m^2$$
$$x_1 + x_2 = 19.328{,}2612938937\ m^2$$

- If farmers want to plant rice by carrying out 3 phases in stages, they will get it

$$x_1 + x_2 + x_3 =$$
$$6.973{,}96270416038\ m^2 + 7.220{,}672210525681\ m^2 + 1.2107{,}58908336806\ m^2$$
$$x_1 + x_2 + x_3 = 26.302{,}2239980541\ m^2$$

- If farmers want to make it based on the area of land they own, they can create a new equation to see or predict the amount of rice production, as follows:

$$6.973{,}96270416038\ (V_1) + 7.220{,}672210525681 (V_2) + 1.2107{,}58908336806\ (G)$$

Under the condition :

$$(G) = luas\ lahan\ yang\ ingin\ ditanam\ pertama\ dalam\ hektar$$
$$(V_2) = luas\ lahan\ yang\ ingin\ ditanam\ kedua\ dalam\ hektar$$
$$(V_1) = luas\ lahan\ yang\ ingin\ ditanam\ terakhir\ dalam\ hektar$$

- So, for example, if a farmer has 300 hectare and will plant three phases with a distribution of 100 hectare in each phase, he will get

$$6.973{,}96270416038\ (100) + 7.220{,}672210525681 (100) + 12.107{,}58908336806\ (100)$$
$$= 2.630.222{,}399805410\ m^2$$

So farmers will get a harvest of $2.630.222{,}399805410\ m^2$

- And if farmers want to compare with one phase, they get:

$6.973{,}96270416038\ (0) + 7.220{,}672210525681(0) + 12.107{,}58908336806\ (300)$
$= 3.632.276{,}725010418\ m^2$

- From the comparison of the two production results, you can also see the difference between using three phases and one phase

$2.630.222{,}399805410\ m^2 - 3.632.276{,}725010418\ m^2$
$= -1.002.054{,}325205008\ m^2$

So it can be concluded, farmers will experience a loss of $1.002.054{,}325205008\ m^2$ when farmers only plant rice in one phase.

The title of the paper should appear on the top edge of the first page of the document. Type the title in uppercase and lowercase letters, align left margin and in Times New Roman 16-point, boldface type. Capitalize the first letter of nouns, pronouns, verbs, adjectives, and adverbs; do not capitalize articles, coordinate conjunctions, or prepositions, unless the title begins with such a word. In case the title is two or more lines, single-space between the lines. Insert a blank single-spaced line after the title.

Results are the main part of scientific articles, containing: final results without data analysis process, hypothesis testing results. Results can be presented with tables or graphs, to clarify the results verbally.

4. Conclusion

From the results of calculations and discussions, we can conclude that the amount of rice production if planting is only done once or in one phase is around $12.107{,}58908336806\ m^2$ yields. Furthermore, if planting is carried out twice in the phase range, it is obtained around $19.328{,}2612938937\ m^2$. And when planting is done as many as three times in the span of the harvest phase that is obtained around $26.302{,}2239980541\ m^2$. By looking at the calculation results, the most favorable condition for farmers in Karawang to produce maximum rice production is to use 3 gradual phases in rice planting.

From the results of calculations and comparisons, if farmers want to get maximum production and minimum losses, it is better to plant in stages, provided that the first planting is made less than the second and third plantings. This is to prevent losses due to other external factors. In this way, the next steps can be to consider developing a more complex model, deeper understanding of the research variables and collecting data that takes into account other factors that may influence rice growth, such as soil conditions, nutrient content, fertilizer use and rainfall patterns. Integrating these variables in the analysis can produce more accurate predictions.

This calculation was only carried out for journals that discussed agricultural products in the Karawang area. So this calculation is not a general description for a farmer to predict rice farming results. However, if an area has accurate data with several variables that are considered to be supportive, then applying the Gauss-Jordan method can be the fastest and most accurate solution for predicting rice production results.

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