Calculation of rice field embankment coefficient using high-resolution satellite imagery

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Abstract: Estimating rice production is vital in ensuring economic stability. One of the critical element in the estimation is the information on the width of the rice field. The uncertainty on this aspect is exacerbated by which the rice field is calculated. The current method only considers the width of the fields, without taking into account the rice field embankment. The width of the embankment is usually between 25 cm to several meters. Neglecting the contribution of this embankment to the overall width of the rice fields can result in overestimation to the rice production. In this research, the coefficient of rice field embankment is calculated. The data used are from high-resolution satellite imagery of Pleades, SPOT-6, Worldview, and GeoEye. UAV data from rice fields in Yogyakarta was used as control data. The study area covers rice fields in Bengkulu, Jambi, Riau, Bangka Belitung, Sulawesi Tenggara, Sulawesi Barat, Sulawesi Tengah, Gorontalo, Maluku, Nusa Tenggara Timur, and Papua. Two types of digitization methods were used. The first one is a rice field without any embankment incorporated. Only road or irrigation channel wider than 2.5 meters were included. The second one is a rice field with embankment feature digitized. The coefficient of the embankment is calculated by dividing the width of the embankment with the width of rice fields without embankment. For a different location, the coefficient is different, between 1% - 3%. Types of rice fields, satellite imagery being used, and topography affect the coefficient.

1. Introduction

Rice is the most important food in Indonesia since the largest portion of the population depends on rice for their daily diet. As such, the price of rice needs to be monitored to maintain its affordability while at the same time, also ensuring farmers being paid well. Estimating rice production is vital in achieving this goal.

Estimating rice production involving several factors, among them is estimating how wide the rice field is. This task is not easy since many circumstances affecting the method to calculate the width of the rice field. This is the reason why in the past there were several numbers of the width of rice fields produced by different government ministry or agencies. The first one is in the location and distribution of it. Rice fields located in the area as far as Aceh to Merauke. In some areas, the rice fields are concentrated in nearby location while in other parts, they scattered in remote areas. The second aspect is on the definition of rice field, whether a dormant field detected in satellite imagery or during field survey can be considered productive rice field. The third is on the base data, whether high-resolution satellite imageries or aerial photos available or not.

Remote sensing technology can provide fast and accurate information on an agriculture production system [1]. In case these data do not become available, the calculation will have to depend on coarser
data. The latter will produce less accurate estimates. Should the base data to produce rice field map is available, the method with which rice field is digitized needs to be carefully examined.

Two methods are usually employed to map the rice field. The first method assumes that the whole rice field in a particular location, which is not separated by wide road or river, as one big field. The existence of embankment is not taken into account. On the other hand, the second method considers that there is embankment between individual parcels that need to be incorporated in mapping the rice field. Figure 1 illustrates the situation. The dashed line represents field digitized using the fist method, while the green box depicts the second method.

![Figure 1. Illustration of rice field](image)

Estimating rice production involves estimation of the width of the green box, which is the actual land where rice will be cultivated. To digitize all rice field parcel needs considerable time and resources, in addition to the availability of high resolution of satellite imageries or aerial photos. Both of them are not always available due to data provision or funding issue.

To overcome these impediments, it is common practice to digitize outer boundaries of a unified set of rice field parcels not separated by road, river, or settlement area. It will cost time and money considerably. However, to better reflect the actual width of the rice field that can be used for cultivation, it is necessary to have an estimate on the width of the embankment. The width of the embankment needs to be taken out in the estimation.

This paper investigates the coefficient of embankment on various topographical condition using a different type of satellite images. This paper extends the investigation of Ramadhani [2]. The study area was on a flat and hilly area, in eight provinces in Indonesia. A UAV photo on rice field was also used to show the implementation of the method in a very clear image.

2. Method

2.1. Study Area
The rice fields in this study cover area with flat terrain and hilly area. Rice fields mapping in seven provinces were processed using satellite imageries, while in one provinces mapped using UAV photos. For the flat terrain, the locations are Riau, Parigi Moutong, Gorontalo, Papua, and Yogyakarta (UAV). For rice fields in the hilly area, we use data from Riau, Jambi, Bangka Belitung, and Nusa Tenggara Timur.

2.2. Data
Satellite data for this study were obtained from Badan Informasi Geospasial (BIG) as part of its rice field mapping activities. The SPOT-6 data has 1.5 m spatial resolution in pan-sharpened mode. UAV
photos were previously used for village mapping research, acquired in May 2018. It has a spatial resolution of 5 cm.

2.3. Method
The research involves two steps, digitizing rice fields and their embankments, and calculation of the coefficient of the embankment. The manual digitizing method was used in creating rice fields data. Google satellite images were used as guidance whenever the SPOT-6 data was not so clear. In all study area, Google satellites data provide a clearer visual of the rice fields. Two features were digitized, the outer boundary of the rice field, and field embankments. The process is illustrated in Figure 2.

![Digitizing process](image)

**Figure 2.** Digitizing process, with digitizing outer boundary (a), assisted by Google Satellite images (b), and digitizing field embankments (c).

By doing this, the rice field parcels can be automatically obtained. Outer boundary represents the gross width, while the sum of all rice field parcels represents net width. Here, the width of embankments can be calculated by subtracting the gross width using the net width. The result was then used to calculate the coefficient of the embankment.

The second step is to calculate the coefficient of the embankment. According to the Indonesian Bureau of Statistic, the calculation of the coefficient of the embankment ($K_p$) can be executed using the following formulae:

\[ L_b = L_k - L_p \]  \hspace{1cm} (1)

where $L_b$ is a net width of the rice field, $L_k$ is the gross width, and $L_p$ is the width of the embankment. The formulae can be re-write as

\[ L_p = L_k - L_b \]  \hspace{1cm} (2)

Finally, $K_p$ can be obtained by using this formula

\[ K_p = \frac{L_p}{L_k} \]  \hspace{1cm} (3)

3. Results

3.1. Coefficient of embankment on flat terrain
The rice field on a flat terrain typically has the straight embankment, the area is wide and orderly form. They are not constrained by topography. However, the width of the field is affected by land availability and ownership. Figure 2 – 4 show the rice field identified in flat terrain in Riau, Sulawesi Tengah,
Gorontalo, Papua Barat, and Yogyakarta. Rice field in Yogyakarta was digitized on UAV photos. The red line represents embankment, while the yellow line represents the outer boundary of the rice field.

![Figure 3](image1)  
**Figure 3.** Rice fields in Rupat, Riau (a and b) and Moutong, Sulawesi Tengah (c and d).

![Figure 4](image2)  
**Figure 4.** Rice fields in Paguyaman, Gorontalo (a and b) and Kurulu, Papua (c).

![Figure 5](image3)  
**Figure 5.** Rice fields in Karangwuni, DI Yogyakarta digitized on UAV photos.

Rice field in Figure 2a has a total width of 25,798 m², and width of the embankment of 1.748 m². In Figure 2b, the total width of the rice field is 101.984 m², with a width of the embankment is 4.847 m². Rice field in Figure 2c and 2d are wider than the rice field in Figure 2a and 2b. In figure 2c, the rice field has a total width of 127,797 m² with embankment width of 9,919 m². Therefore, the total width of
the field parcel is 117,877 m². Rice field in Figure 2d has a total width of 144,681 m², and embankment width of 10,953 m². The same calculation was conducted for rice field in Figure 3 and Figure 4. The result is presented in Table 1.

Table 1. Width of rice field and embankments in flat terrain.

| Location       | Width of (m²) | Gross width | Embankment | Net width |
|----------------|---------------|-------------|------------|-----------|
| Paguyaman (3a) | 187,376       | 14,000      | 173,376    |
| Paguyaman (3b) | 199,123       | 12,514      | 186,609    |
| Kurulu (3c)    | 84,676        | 6,626       | 78,050     |
| Karangwuni 1   | 47,521        | 5,256       | 39,398     |
| Karangwuni 2   | 98,600        | 8,123       | 90,477     |
| Karangwuni 3   | 125,576       | 8,762       | 116,814    |
| Karangwuni 4   | 165,722       | 11,369      | 154,353    |

Based on the gross width, and embankment width, the embankment coefficient was calculated for the rice field in flat terrain. The lowest coefficient is found in Rupat 2 (0.047); the highest is Moutong 1 and Kurulu (0.078). The average coefficient of the embankment is 0.069. The result is presented as follow.

Rupat (1)

\[ KP = \frac{1.748}{25.798} = 0.068 \]

Rupat (2)

\[ KP = \frac{4.847}{101.904} = 0.047 \]

Moutong (1)

\[ KP = \frac{9.919}{127.797} = 0.078 \]

Moutong (2)

\[ KP = \frac{10.953}{144.681} = 0.076 \]

Paguyaman (1)

\[ KP = \frac{14.000}{187.376} = 0.075 \]

Paguyaman (2)

\[ KP = \frac{12.514}{199.123} = 0.063 \]

Kurulu

\[ KP = \frac{6.625}{84.676} = 0.078 \]

The coefficient of embankment in Karangwuni is calculated separately because the base data is different. The difference is also in the form of the field. Rice field in Karangwuni is distinctively narrow ones with longer on the side. The number of embankment is higher compared to other location. Therefore, the embankment will have higher width. This figure is an evident of the effect of higher number of embankment on the net width of rice field. Detailed calculation is presented as follow.

Area 1

\[ KP = \frac{5.256}{47.521} = 0.112 \]

Area 2

\[ KP = \frac{8123}{127797} = 0.082 \]

The lowest coefficient is 0.069, while the highest is 0.112. The average is 0.083. Higher value in this location is mainly caused by a higher number of embankments and forms of rice fields.
3.2. Coefficient of embankment on hilly terrain
The rice field on a hilly area with terrain typically has the curved embankment, the embankment follows the topography, and the field parcel is usually smaller. They are constrained by topography. Figure 5–6 shows the rice field identified in flat terrain in Riau, Bangka Belitung, Jambi, and Nusa Tenggara Timur. The red line represents embankment, while the yellow line represents the outer boundary of the rice field.

![Figure 6. Rice fields in Rambah, Riau (a and b), and Mendo Barat, Bangka Belitung (c and d).](image)

![Figure 7. Rice fields in Maro Sebo, Jambi (a) and Tabir, Jambi (b), and Rote Tengah, Nusa Tenggara Timur (d).](image)

After all rice fields and embankments were digitized, the width of the total rice field, embankment, and field parcel were calculated. The result is presented in Table 2.

Table 2. Width of rice field and embankments in rolling terrain.

| Location     | Width of (m²) | Gross width | Embankment | Net width |
|--------------|--------------|-------------|------------|-----------|
|              |              | Gross width | Embankment | Net width |
| Rambah 1     |              | 23,714      | 3,254      | 20,460    |
| Rambah 2     |              | 37,609      | 3,609      | 34,000    |
| Mendo Barat 1|              | 742,328     | 89,799     | 652,529   |
| Mendo Barat 2|              | 164,915     | 18,143     | 146,772   |
| Maro Sebo    |              | 525,722     | 36,411     | 489,311   |
| Tabir        |              | 229,530     | 19,288     | 210,242   |
| Rote Tengah  |              | 145,585     | 15,293     | 130,292   |
Based on the gross width, and embankment width, the embankment coefficient was calculated for rice field in hilly area. The result is presented as follow.

\[
\begin{align*}
\text{Rambah (1)} & \quad KP = \frac{3,254}{23,714} = 0.137 \\
\text{Rambah (2)} & \quad KP = \frac{3,609}{37,609} = 0.096 \\
\text{Mendo Barat (1)} & \quad KP = \frac{89.799}{742.328} = 0.121 \\
\text{Mendo Barat (2)} & \quad KP = \frac{18.143}{164.915} = 0.110 \\
\text{Maro Sebo} & \quad KP = \frac{36.411}{525.722} = 0.069 \\
\text{Tubir} & \quad KP = \frac{19.288}{229.530} = 0.084 \\
\text{Rote Tengah} & \quad KP = \frac{15.293}{145.585} = 0.105
\end{align*}
\]

From the calculation, it is found that the lowest coefficient is found in Maro Sebo (0.069), the highest is in Rambah (0.137). The average coefficient of the embankment is 0.103.

Coefficient of embankment in flat terrain is lower compared to the hilly area. The lowest coefficient is similar, at 6.9%. This number indicates that for every 100 m\(^2\) of rice field, approximately 7 m\(^2\) is used for the embankment. However, the average coefficient is differed by 2%. This means that rice field in flat terrain generally has higher net width compared to the rice field in a hilly area. The comparison is presented in Table 3.

| Topography | Lowest | Average | Highest |
|------------|--------|---------|---------|
| Flat       | 0.069  | 0.083   | 0.112   |
| Hilly      | 0.069  | 0.103   | 0.137   |

4. Conclusion
Rice field and embankment have been digitized based on high-resolution satellite imageries. The maps consist of three elements, outer boundary, which represents the gross width, embankment, and field parcel or net width. Coefficient of embankment in flat terrain and the hilly area has been calculated. In average, 8% of rice field in flat terrain is used for the embankment. On the hilly area, embankment use around 10% of the rice field.

The coefficient in flat terrain is lower compared to the hilly area. Net width of rice field which can be used for cultivation is, therefore, wider. Local condition on cultivation model may affect the coefficient, as shown in the rice field in Karangwuni.

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6. Reference

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