Analysis of water availability and planting index in dams in Bedadung watershed

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Abstract. The increasing population causes the government to work to improve food security. One of the policies adopted is to increase the productivity of agricultural land. Increased productivity of agricultural land can be increased by increasing the crop index. Planting index is the total area for crops per planting season for a year. In this case support from irrigation, the sector is very important. From the preliminary survey in the study area, we found some damage to the irrigation assets that might reduce the performance of the assets which caused the crop index to be lower than the maximum crop index (300%). This study aims to (1) calculate the availability of irrigation water, (2) calculate the crop index, and (3) analyze the potential increase in the crop index and the expansion of agricultural land. The results showed that there were 80 dams (44.4%) experienced abundant water but had a crop index value of less than 300%. Thus, the service area of 80 dams can be increased the value of the planting index to 300%. While there are 100 dams (55.6%) experiencing water shortages. In this case, the recommendations that can be given are providing water supply through the construction of a reservoir or changing the pattern of planting paddy - paddy - palawija - palawija. We conclude that water delivery in the Bedadung Watershed area is not effective. This can be caused by damage to irrigation assets. Therefore, a recommendation that can be given for further research is the effect of irrigation asset performance on irrigation services.

1. Introduction
High population and declining agricultural land are the main challenges for policymakers to improve food security [1]. Food safety is the amount of food that is available in proportion to the needs and abilities of people to get it. Food security is the condition for the fulfillment of food of every person with good conditions in terms of quality, variety, nutrition, and safety [2]. Food security can be fulfilled by optimizing land use by taking into account the suitability of land for a type of plant.

Efforts to improve food security are carried out by increasing crop productivity. Increased productivity can be supported by sufficient conservation water at each planting season [3]. Irrigation water usually comes from rivers or dams that flow through open channels or pipes into agricultural areas [4].

Achievement of this production target must be supported by the availability of water which is supported by the performance of the dams that serve to drain water into agricultural land. Based on preliminary survey results, it shows that there is damage to the irrigation assets which causes the water
distribution from upstream to downstream does not optimally, which in turn will affect agricultural production from agricultural land.

The indicator used in this study was the achievement of a 300% cropping index for three planting seasons. The planting season in question is the Rainy Season (MH), Dry Season I (MK I), and Dry Season II (MK II). If the crop index value is less than 300%, then solutions must be sought to increase that value.

The purpose of this study was to determine the availability of irrigation water and cropping index as well as the potential for increasing agricultural productivity through the crop index in the Bedadung Watershed.

2. Methodology

2.1. Research sites

The study was conducted in 2019 on dams located in the Bedadung Watershed. The Bedadung Watershed is an area with the main river, the Bedadung River. Jember Regency has 3 main rivers, namely Bedadung River, Mayang River, and Tanggul River. Bedadung River is the largest river in Jember Regency. Administratively, the Bedadung Watershed is located in Jember Regency, Bondowoso Regency, Banyuwangi Regency, and Probolinggo Regency. The Bedadung watershed has an area of 838.81 km². The Bedadung River Watershed Map is presented in Figure 1 below.

![Map of Bedadung watershed](image)

**Figure 1.** Map of Bedadung watershed

2.2. Research stages

2.2.1. Asset inventory

The asset inventory is carried out to determine the dams that are in the Bedadung Watershed. Dams in the Bedadung Watershed are known based on the irrigation network scheme owned by each manager of the dams. The search results show that the dams in the Bedadung watershed are managed by 6 management units which are presented in Table 1 below.

| Management Unit    | Dams | Service Area (ha) |
|--------------------|------|-------------------|
| UPT Curah Malang   | 1    | 13,245            |
| UPT Kalisat        | 5    | 3,655             |
| Management Unit | Dams | Service Area (ha) |
|-----------------|------|------------------|
| UPT Patrang     | 88   | 4,023            |
| UPT Rambipuji   | 49   | 4,366            |
| UPT Sukowono    | 33   | 2,597            |
| UPT Sumbersari  | 4    | 2,058            |
| Total           | 180  | 29,944           |

2.2.2. Data processing In processing data, the data needed is as follows.

a. Plant Data
Plant data is used to determine the Relative Palawija Area (LPR). The determination of the LPR value is based on the widest area data for three times the growing season. How to determine the value of the Relative Palawija Area (LPR) using the following equation [5].

\[
LPR = \frac{A_{crop}}{C_{crop}} \times Crop
\]

Information:
LPR  = Relative Palawija Area (ha.pol)
A_{crop} = Planted area (ha)
C_{crop} = Plant type coefficient

The coefficient values of plant species can be seen in the following Table 2 [6].

| Type of Plant | Planting Coefficient (C) |
|---------------|--------------------------|
| Palawija      | 1                        |

| Paddy on Rainy Season |
|-----------------------|
| a. Nursery            | 20                      |
| b. Land Cultivation   | 6                       |
| c. Growth             | 4                       |

| Paddy which is allowed to be planted |
|--------------------------------------|
| a. Nursery                           | 20                      |
| Type of Plant                                | Planting Coefficient (C) |
|---------------------------------------------|--------------------------|
| b. Land Cultivation                        | 6                        |
| c. Growth                                  | 4                        |
| Paddy that is not allowed to be planted     | 1                        |

**Tebu**

| Type of Plant | Planting Coefficient (C) |
|---------------|--------------------------|
| a. Nursery    | 1.5                      |
| b. Young      | 1.5                      |
| c. Old        | 0                        |
| Tobacco or Rosela | 1                      |

Besides, planting data is used to determine the value of the cropping index. Planting index values are based on an area three times the growing season. If the land is planted during the three growing seasons, namely Rainy Season (MH), Dry Season I (MK I), and Dry Season II (MK II), then the crop index value is 300% [7].

The maximum value of the crop index is 300% for three growing seasons (rainy season, a dry season I, and dry season II) [8]. The crop index can be determined by the following equation.

\[
IP = \frac{LT_1 + LT_2 + LT_3}{L} \times 100\% 
\]  

(2)

**Information:**

- \( IP \) = Planting Index (%)
- \( LT_1 \) = Area of Planting Season I (ha)
- \( LT_2 \) = Area of Planting Season II (ha)
- \( LT_3 \) = Area of Planting Season III (ha)
- \( L \) = Total Area (ha)

b. Debit data

Each dam has a discharge that is used to irrigate the service area following the records in the building measurements. Discharge flowed into agricultural land must be following discharge requirements.

Discharge data processing is carried out to determine the measured discharge (existing) for each dam. Debit data obtained based on the results of the recording of debit on Form 05-E on each dam by each dam's management unit is the value of the existing measured debits while the determination of the discharge requirements for each service area of each dam is based on the relative area of palawija (LPR) and secondary crops factors relative (FPR). The equation used to determine the plant discharge requirements is as follows [4].

\[
Q = LPR \times FPR 
\]  

(3)

**Information:**

- \( Q \) = Debit (L / sec)
- \( LPR \) = Relative Palawija Area (ha / pol)
FPR  = Relative Palawija Factor (l / sec / Ha.pol)

FPR value can be determined based on the type of land service area. The relative palawija factor is the discharge of water in the main building needed for plants per hectare [7]. The value of the relative crop factor (FPR) can be seen in the following table 3 [10].

| Soil Type | FPR (l/sec/Ha.pol) |
|-----------|-------------------|
|           | Less Water | Enough Water | More Water |
| Aluvial   | 0.18      | 0.18 – 0.36 | 0.36       |
| Latosol   | 0.12      | 0.12 – 0.23 | 0.23       |
| Grumusol  | 0.06      | 0.06 – 0.12 | 0.12       |

3. Results and discussion

3.1. Rain

Jember Regency has 77 rain stations with 38 rain stations in the Das Bedadung area. The results of data recapitulation show that Das Bedadung has a value of 7 for the Wet Month and a value of 4 for the Dry Month. So, it can be concluded that the Bedadung watershed is in the type B climate classification, which is an area that can be planted twice a year with short-lived varieties and short dry seasons sufficient for palawija plants.

3.2 Plants water needs

In the Bedadung watershed 180 dams irrigate 29,944 hectare of agricultural land. Calculation results show that there are 80 dams (44.4%) having excess water / abundant water but have a cropping index of less than 300%. This shows that there are dams with a service area that can be expanded to optimize the availability of water which can then increase agricultural production.

However, the calculation results also show that as many as 100 dams (55.6%) experienced water shortages with a crop index of less than 300%. The addition of water to meet water shortages can be done by building reservoirs to help supply water to agricultural land.

Also, to reduce water shortages on agricultural land can be done by changing cropping patterns. Based on plant data for each dam shows that the cropping pattern applied in paddy - paddy - paddy. Changes in cropping patterns can be changed from paddy - paddy to paddy - palawija - palawija. The recommended crops are corn. Bedadung watershed has land suitability for maize S2 category covering an area of 476.66 km2 (56.83%) and S3 category paddy totaling 64.56 km2 (76.97%) [11]. Determination of suitable planting patterns can be based on the availability of water every planting season [12].

The results showed that the agricultural land in the Bedadung watershed began to plant paddy in the rain season in October period III, a total of 78 irrigation areas (43.3%). Due to the initial difference in planting, the amount of water needed for each plant is different - which can cause agricultural land that does not get water. Farmers who are not in unison in starting this paddy planting activity can cause the planting index to be less than 300% due to other agricultural lands that do not get water. Different planting schedules cause the water requirements of each plant to be different [13].
3.3 Planting Index

In supporting the effectiveness in the use of agricultural land, it is needed an appropriate planting pattern. The cropping pattern used should also be adjusted based on the availability of water that can flow from the dams to the agricultural land. Based on the results of data interpretation, agricultural land in the Bedadung Watershed adopts the paddy-paddy-paddy planting pattern. However, the application of this cropping pattern is not complemented by the availability of water that can irrigate agricultural land, causing the crop index to have a value of less than 300%.

The results showed that of the 180 dams found in the Bedadung Watershed, 120 dams (66.7%) had cropping indices of more than 200% and 60 dams (33.33%) had cropping indices ranging from less than 200%. However, none of the dams in the Bedadung Watershed have a crop index of 300% according to the provisions. Based on these results, it is necessary to change the new cropping pattern to support the cropping index so that it can reach a value of 300%.

Determination of cropping patterns can be done based on cropping index and water availability [14]. Planting patterns applied based on the cropping index are presented in the following table.

| Cropping Index | Cropping Patterns | Water Availability Requirements |
|----------------|-------------------|--------------------------------|
| 300%           | Paddy – Paddy – Palawija | The waterfall is available in sufficient quantities to a lot |
|                | Paddy – Paddy – Paddy |                                |
|                | Paddy – Palawija – Palawija |                                |
| 200% - 300%    | Paddy – Paddy – Bera | Water must be guaranteed in sufficient quantities |
|                | Paddy – Palawija – Bera |                                |
| 200%           | Palawija – Paddy – Bera | Areas that tend to always experience water shortages |

Planting an index of less than 300% can be caused by ineffective water distribution. Water distribution can be effective if supported by good irrigation facilities. Reducing the condition and function of assets can result in suboptimal operation and maintenance activities which in turn will affect the availability and efficiency of water delivery [15].

4. Conclusion

In the Bedadung Watershed area, 180 dams irrigate 29,944 hectare of paddy fields, and 80 dams (44.4%) experience abundant water but have a crop index value of less than 300%. While there are 100 dams (55.6%) experiencing water shortages. Thus, changes in cropping patterns based on crop index values are expected to increase crop index values to reach 300%.

Changes in cropping patterns following the availability of irrigation water are expected to increase the cropping index. Changes in cropping patterns based on water availability are also expected to be supported in terms of irrigation infrastructure. Damage to irrigation assets can reduce the effectiveness of water distribution from upstream to downstream agricultural land.

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