Planning Optimization Planning Irrigation Area of Solok
Sumatera West Regency

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Abstract

Solok Regency irrigation network planning which has an area of irrigation land of 3738 ha. The main canals are spread in several areas, namely 43 Irrigation Channels, 17 Dams, 7 Reservoirs and 2 lakes which are still functioning in Solok Regency. The poverty rate in Solok Regency is still quite high, reaching 27.487%. The data includes secondary data on 10-year rainfall data from Kayu Aro, Bayur Maritime Bay Methodology, Padang Panjang Geophysics and 10-year climatology from Kayu Aro Climatology Station. The calculation method used is the intensity of theissen rainfall method, Evapotranspiration of the modified Penman method, the reliable discharge of the DR.FJ Mock method, the cropping pattern, and the need for irrigation water. The most efficient and optimal planting pattern obtained is PADI-PADI-CORN with large irrigation water requirements in tertiary plots (NFR tertiary plots) ranging from 0 - 1,546 ltr / sec / ha with a maximum of 1,546 ltr / sec / ha in September II, whereas Irrigation water demand in the intake (DR intake) ranges from 0 to 2,378 ltr / sec / ha with a maximum of 2,378 ltr / sec / ha in September II.

The mainstay discharge available in the Pauh Tinggi Irrigation Network Planning is very abundant with the mainstay discharge (Q80) for irrigation, the maximum mainstay discharge (Q80) occurs in April I with 10.482 ltr / sec / ha and minimum in December II with 3,930 ltr / sec / ha. Based on the mainstay discharge results above it can be stated that the water balance / water balance between the mainstay discharge Q80 and the need for irrigation water experienced a large surplus.

1. Introduction

Water is a natural resource that is very important for the survival of all living things. Water is also very necessary for industrial activities, fisheries, agriculture and other businesses. In the use of water often occurs inadvertently in the use and utilization so that efforts are needed to maintain the balance between the availability and demand of water through development, preservation, repair and protection [1].

Indonesia is a region with a large portion of agricultural area, therefore most of the population looks for a living as farmers. One of them is Solok Regency which has an area of 3738 ha with an area of 3106 ha is agricultural land and

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234.39 ha is non-agricultural land [2]. With this area, a good irrigation system is needed. The use of irrigation in Solok Regency is not balanced with the availability of water available. With the problem of the difference between water availability and water needs, it is necessary to do the right planting pattern in the Irrigation District of Solok Regency. Aiming to take advantage of excess water in the rainy season to supply water shortages in the dry season. Through Alternative Planting Patterns (PTT) can be obtained maximum yield of crops. By maximizing the existing agricultural areas indirectly the economy in the irrigation area will also increase. Besides being able to optimize the yield of PTT crops, it can also increase farmers' income and the economy in Solok Regency.

Solok Regency area 39.66% of the majority of the population is eyed as farmers with an area of 3106 ha of agricultural land and 234.39 ha of non-agricultural land. The poverty rate in Solok Regency is still quite high, reaching 27,487 [3]Thus, to improve the economy of the people of Solok Regency, one of the efforts that can be done is to increase business in the agricultural sector by planning optimization of farming patterns in the agricultural area.

2. Theoretical

2.1. Definition of Irrigation

Irrigation is activities related to the efforts to get rice water, fields, plantations and other agricultural businesses, swamps, fisheries. The main business involves the creation of facilities and infrastructure to distribute water to the fields regularly and remove excess water that is no longer needed by agricultural businesses. [4]

2.2. Irrigation Network

Based on how water flow measurements are regulated and facilities are complete, irrigation networks can be divided into three levels, see Table 2.1:

1. Simple Irrigation Networks
2. Semiteknis Irrigation Network
3. Technical Irrigation Network

| Klasifikasi jaringan irigasi | Teknis | Semiteknis | Sederhana |
|-------------------------------|--------|------------|-----------|
| 1 Bangunan Utama              | Bangunan permanen | Bangunan permanen atau semi permanen | Bangunan sementara |
| 2 Kemampuan bangunan dalam mengukur dan mengatur debit | Baik | Sedang | Jelek |
| 3 Jaringan saluran             | Saluran irigasi dan pembuangan terpisah | Saluran irigasi dan pembuangan tidak terpisah | Saluran irigasi dan pembuangan jadi satu |
| 4 Petak terier                 | Dikembangkan sepenuhnya | Belum dikembangkan atau diberat secara jangka | Belum ada jaringan terpisah yang dikembangkan |
| 5 Efisiensi secara keseluruhan | Tinggi 50 – 60% (Ancak-ancak) | Sedang 40 – 50% (Ancak-ancak) | Kurang < 40% (Ancak-ancak) |
| 6 Ukuran                      | Tak ada batasan | Sampai 2.000 ha | Tak lebih dari 500 ha |
| 7 Jalan Usaha Tani            | Ada ke seluas areal | Hanya sebagian areal | Gendangan tidak ada |
| 8 Kondisi O & P               | Ada instansi yang menangani - Dilaksanakan teratur | Belum beratur | Tidak ada O & P |

Fig. 1 Table of Irrigation Network Classification (in Indonesia) (Source:KP-01 Irrigation Planning Standards)
Simple Network, In simple irrigation, see fig. 2. Water distribution is not measured or regulated, more water will flow into the sewer. The water user farmers are incorporated in the same irrigation network group, so there is no need for government involvement in this kind of irrigation network organization. Water supplies are usually abundant with slopes ranging from moderate to steep. Therefore, there is almost no need for difficult techniques for the water distribution system. [6]

Semiteknis Irrigation, In many ways, the only difference between a simple irrigation network and a semitek technical network is that the semitek technical network is located on a river complete with a retrieval building and measuring structure downstream. Some permanent buildings might also be built on a network of canals. Water distribution systems are usually similar to simple networks (see fig. 3). It is possible that retrieval is used to serve / irrigate a wider area than the service area on a simple network. Therefore the costs are borne by more service areas. The organization will be more complicated if the permanent building takes the form of taking buildings from the river, because it requires more involvement from the government, in this case the Department of Public Works. [6]
Technical Irrigation. One of the principles in technical network planning is the separation between irrigation networks and waster / pematus networks. This means that both the irrigation channel and the waster still work in accordance with their respective functions, from the base to the tip. Irrigation channels drain irrigation water into the fields and the drainage channel flows more water from the fields to the natural drainage channel which will then be forwarded to the sea (see fig. 4). The advantages that can be obtained from such a combined network are the more economical use of water and lower channel construction costs, because the carrier channel can be made shorter with a smaller capacity.

The disadvantages include that this kind of network is more difficult to regulate and operate frequently, floods more quickly, and shows uneven water distribution. Certain buildings in the network will have properties such as weirs and are relatively expensive. [6]

Fig. 4 Technical Irrigation Networks (in Indonesia)
(Source: KP-01 Irrigation Planning Standards)

2.3. Evapotranspiration

Analyzing climatology data in the form of data on air temperature, humidity, duration of solar radiation, and wind speed at the climatology station closest to the Irrigation area to look for potential evapotranspiration [1].

The method used here is the Penman Modification method. To calculate ET0 using the Penman modification method, the formulas used are:

\[
\begin{align*}
    e_s &= 611 \exp \left( \frac{17.27 \ T}{237.3 + T} \right) \\
    e_d &= e_s \ r \\
    E &= B (e_s - e_d) \\
    B &= \frac{0.102 \ \mu \ r}{(\ln \left( \frac{E}{e_d} \right))^2} \\
    L_n &= \sigma T^4 (0.56 - 0.092 \ \sqrt{e_d} \ (0.1 + 0.9 \ \frac{B}{N}) \ N) \\
    S_t &= S_0 \ (a + (b \ x \ n/12.1)) \\
    S_s &= S_t (1 - \alpha) \\
    R_n &= S_n - L_n \\
    l_v &= 597.3 - 0.56 \ T
\end{align*}
\]
\[
\begin{align*}
E_n &= \frac{R_n}{\rho_w l_v} \\
ET_0 &= \frac{\beta En + E}{\beta + 1}
\end{align*}
\]

with:
- A = reflection coefficient (albedo)
- B = temperature function
- \(\Sigma\) = Stevan-Boltzman constant (1.17. 10^-7 cal / cm^2 / K^4 / day)
- \(P_w\) = density of water (1 gr / cm^3)
- ed = water vapor pressure at elevation 2 m on the surface (mmHg)
- ice = saturated water vapor pressure
- E = Evaporation (mm / day)
- En = depth of evaporation (cm / day)
- ET0 = potential Evapotranspiration (mm / day)
- lv = latent heat for evaporation (cal / gram)
- Ln = Long-wave radiation emitted earth (cal / cm^2 / day)
- n / N = duration of daily sun exposure (%)
- N = Maximum exposure duration of hours=12.1 hours (Triadmojo, 2014: 62)
- r = relative humidity (%)
- Rn = Net radiation
- S0 = Shortwave radiation on the outer edge atmosphere (cal / cm^2 / day)
- Sn = Net absorbed solar radiation Earth surface
- T = absolute temperature at elevation 2 m above surface (0K) (0C)
- u2 = Wind speed at a distance of 2 m above surface (m / sec)
- z0 = high roughness given by table 2.6
- z2 = 2 meters above sea level

| Table 1 Values a and b |
|------------------------|
| Area                  | a   | b   |
| Cold and temperate    | 0.18| 0.55|
| Dry tropics           | 0.25| 0.45|
| Wet tropics           | 0.29| 0.42|

(Source: Triatmodjo [5])

| Table 2 The \(\beta\) value based on temperature |
|-----------------------------------------------|
| T (°C)            | \(\beta = \Delta/\gamma\) |
|-------------------|---------------------|
| 0                 | 0.68                |
| 5                 | 0.93                |
| 10                | 1.25                |
| 15                | 1.66                |
| 20                | 2.19                |
| 25                | 2.86                |
| 30                | 3.69                |
| 35                | 4.73                |

(Source: Triatmodjo [5])

| Table 3 The \(\alpha\) value (albedo) |
|--------------------------------------|
| Type of face | Albedo (\(\alpha\)) |
|-------------|---------------------|
| Open water  | 0.05                |
| Rock        | 0.12                |
| Sand        | 0.10                |
| Dry soil    | 0.14                |

(Source: Triatmodjo [5])
| Type of face | Albedo (α) |
|------------|------------|
| Wet ground | 0,08 - 0,09 |
| Forest     | 0,05 - 0,20 |
| Grass      | 0,10 - 0,33 |
| Dry grass  | 0,15 - 0,25 |
| Snow       | 0,90        |
| Ice        | 0,40 - 0,50 |
| Plant      | 0,20        |

(Source: Triatmodjo [5])

Table 4 High roughness according to surface type (z0)

| Type of face       | High Roughness |
|--------------------|----------------|
| Ice, flat mud      | 0.001          |
| Ice                | 0.01 – 0.06    |
| Grass (<10) cm     | 0.1 – 2.0      |
| Plants (10-50) cm  | 2 – 5          |
| Plants (1-2) m     | 20             |
| Tree (10-15) m     | 40 - 70        |

Fig. 5 The table of Shortwave radiation on the outer edge of the atmosphere
(Source: Triatmodjo [5])

2.4. Rainfall Data Analysis

Theissen method, weighted average, each rain station is determined by the area of influence based on the polygon formed (drawing the axis lines on the connecting lines between two adjacent rain stations). This method is obtained by making polygons that intersect perpendicular to the middle line connecting two rain stations. Thus each Rₙ
measuring station will be located on a certain polygon An. By calculating the area ratio for each station of magnitude
$= \frac{A_n}{A}$, where A is the area of the shelter area or the total area of the area sought for high rainfall. Average rainfall
is obtained by summing each measure that has an area of influence formed by drawing axis lines perpendicular to the
connecting line between two measure posts [7].

The calculation method is as follows:

$$d = \frac{\frac{A_1 \cdot d_1 + A_2 \cdot d_2 + A_3 \cdot d_3 + \cdots + A_n \cdot d_n}{A}}{A}$$

with:

- $A$ = Area (km$^2$)
- $D$ = Height of average area rainfall (mm/day)
- $d_1, d_2, d_3, \ldots, d_n$ = High rainfall in the post (mm/day)
- $A_1, A_2, A_3, \ldots, A_n$ = Area of influence (km$^2$)
- 1, 2, 3, \ldots, $n$ = Rain station station

2.5. Mainstay Discharge

Dependent flow (dependable flow) is the minimum flow of the river for a predetermined possibility that can be used
for irrigation. The probability of being fulfilled is set at 80% (the possibility that the river discharge is lower than the
mainstay discharge is 20%) [8].

The mainstay rainfall calculation is done by the formula:

$$R_{80} = \frac{n}{5} + 1$$

with:

- $n$ = Rainfall observation period (year)
- $R_{80}$ = Mainstay rainfall of plants with the possibility of rain that is smaller than $R_{80}$ has a probability of 20%,
while those greater or equal to $R_{80}$ have a 80% chance of occurring.

2.6. Rice Water Needs

Irrigation water demand is the amount of water volume needed to meet the needs of evapotranspiration, water loss,
water requirements for plants by paying attention to the amount of water provided by nature through rain and the
contribution of ground water [1].

Calculation of irrigation water needs (NFR) can be done with the formula:

$$NFR = ETC + Pd + P + WLR - Re$$

with:

- NFR = Net Field Requirements in the fields (mm / day)
- ETC = Consumptive water requirements (mm / day)
- Pd = Water requirements for land preparation including nursery (mm / day)
- P = water loss due to percolation (mm / day)
- WLR = Replacement of a layer of standing water (mm / day)
- Re = effective rainfall (mm / day)

2.7. Crop Coefficient ($K_c$)

Plant coefficients are given to link evapotranspiration (ETo) with reference plant evapotranspiration (ETtanam) and
are used in the Penman formula. The coefficient used must be based on continuous experience [6].
Fig. 6 The table of price of paddy crop coefficient (in Indonesia)

| Umur tanaman | RH<sub>n<sub>o</sub><sub>80</sub> < 70% | RH<sub>n<sub>o</sub><sub>80</sub> < 20% |
|---------------|---------------------------------|---------------------------------|
| 12 bulan      | Tahap pertumbuhan               | angin kecil sampai sedang       |
| 24 bulan      |                                | angin kencang                    |
| 0 – 1         | 0 – 2,5                         | 0,25 – 0,25 rimbun *            |
| 1 – 2         | 2,5 – 3,5                       | 0,25 – 0,5 rimbun               |
| 2 – 2,5       | 3,5 – 4,5                       | 0,5 – 0,75 rimbun               |
| 2,5 – 4       | 4,5 – 6                         | 0,75 sampai rimbun              |
| 4 – 10        | 6 – 17                          | penggunaan air puncak            |
| 10 – 11       | 17 – 22                         | awal berbungha                   |
| 11 – 12       | 22 – 24                         | menjadi masak                    |

Fig. 7 The table of price of rice the plant coefficient (in Indonesia)

| Bulan | Nedeco/ Proside | Varietas<sup>2</sup> Biasa | Varietas<sup>3</sup> Unggul | Varietas Biasa | Varietas Unggul |
|-------|-----------------|------------------------------|------------------------------|-----------------|-----------------|
| 0,5   | 1,20            | 1,20                         | 1,20                         | 1,10            | 1,10            |
| 1     | 1,20            | 1,27                         | 1,33                         | 1,10            | 1,10            |
| 1,5   | 1,32            | 1,30                         | 1,30                         | 1,10            | 1,05            |
| 2     | 1,40            | 1,30                         | 1,30                         | 1,10            | 1,05            |
| 2,5   | 1,35            | 1,30                         | 1,30                         | 1,10            | 0,95            |
| 3     | 1,24            | 1,24                         | 0                            | 1,05            | 0,95            |
| 4     | 1,12            | 0                            | 0                            | 1,05            | 0,88            |

Fig. 8 The table of price of Palawija plant coefficient (in Indonesia)

2.8. Effective Rainfall

Effective rainfall is determined by the amount of RH<sub>n</sub> which is the amount of rainfall that can be exceeded as much as 80% or in other words exceeded 8 times out of 10 times. In other words, the amount of rainfall smaller than RH<sub>n</sub> has a possibility of only 20% [1].

When stated with the formula is as follows:

$$R_{80} = \frac{m}{n-1} , m = R_{80} \times (n + 1)$$

with:

- RH<sub>n</sub> = 80% Rainfall
- n = Amount of data
- m = Selected rainfall ranking
The effective rainfall for rice is 70% of the mid-monthly rainfall exceeding 80% of that time [1].

\[ R_{e,padi} = \frac{R_{80} \times 0.7}{\text{Period of observation}} \]

For secondary crops is determined by a monthly period (50% fulfilled) associated with the plant ET table - monthly average and monthly average rainfall [1].

\[ R_{e,palawija} = \frac{R_{80} \times 0.5}{\text{Period of observation}} \]

with:
- \( R_e \) (rice) = Effective rainfall for rice rice field (mm / hr)
- \( R_e \) (Palawija) = Effective rainfall for Palawija (mm / hr)
- \( R_{80} \) = The level of rain that occurs with certain level of confidence (mm)

2.9. Land Preparation (LP)

For the calculation of irrigation needs during land preparation, a method developed by van de Goor and Zijlstra (1968) was used [9]. The method is based on a constant water rate in 1 / sec over the period of land preparation and produces the following formula:

\[ M = E_0 + P = 1.1 \times E_{to} + P \]

with:
- \( e \) = Constants (2.71828)
- \( P_d \) = Irrigation water needs at the rice field level (mm.day)
- \( M \) = Need for water to replace losses water due to evaporation and percolation in the rice field saturated \( M = E_0 + P \) (mm / day)
- \( E_0 \) = Open water evaporation taken 1.1 \( E_{to} \) during land preparation (mm / day)
- \( P \) = Percolation
- \( k = \frac{MT}{S} \)
- \( T \) = Duration of land preparation (days)
- \( S \) = Need for water, for added supply with a 30 mm water layer, ie 200 + 50 = 250 mm, if there is a high land rest inundation of 300 mm

2.10. Consumptive Use (ETc)

Consumptive use is the amount of water used by plants for the photosynthesis of these plants. Consumptive use is calculated by the following formula:

\[ \text{Etc} = K_c \times \text{Eto} \]

Information:
- \( \text{Etc} \) = Evapotranspiration of plants (mm / day)
- \( \text{Eto} \) = Evapotranspiration of reference plants (mm / day)
- \( K_c \) = crop coefficient

2.11. Location and Seepage (P)

The rate of percolation is very dependent on the properties of the soil. Data on percolation will be obtained from soil capability studies. The soil graduation test will be part of this investigation. [6]

Based on the type of soil, the percolation power can be grouped into:
- a. Sandy Loam with percolation 3-6 mm / day
- b. Loam with percolation power of 2-3 mm / day
c. Clay loam with a insulation power of 1-2 mm / day.

2.12. Substitution of Air Lines (WLR)

After fertilization needs to be scheduled and replace the water layer as needed. Replacement is estimated at 2 times 50 mm each month and two months after transplantation (or 3.3 mm / day for 1/2 month) [6].

2.13. Irrigation Efficiency

Irrigation Efficiency is the ratio of the amount of irrigation water used and discharged as stated in (%). A quarter or one third of the amount of water taken will be lost before the water reaches the rice fields caused by exploitation, evaporation and location. Therefore it is necessary to calculate to obtain the amount of water needed by the intake [6].

The overall efficiency value is calculated with the following values:

\[
\text{ef} = \text{tertiary tissue efficiency 60%} \times \text{efficiency secondary tissue 90%} \times \text{tissue efficiency primary 90%} = 65 \%
\]

2.14. Water Needs in Intake Channels (DR)

The need for taking for paddy and secondary crops is the amount of water needed by 1 (one) hectare of rice fields, using a formula:

\[
\text{DR} = \text{NFR} / (\text{ef} \times 8.64)
\]

with:

- DR = Retrieval requirement (l / sec / ha)
- NFR = Rice field water requirements (mm / day)
- Ef = Irrigation Efficiency, Usually taken 65%
- 1 / 8.64 = unit conversion rate (mm / day)

2.15. Water Balance

Water balance calculation is carried out to check whether the available water is sufficient to meet the irrigation water requirements in the project concerned. Calculations are based on weekly or semi-monthly periods [1].

Three main elements are distinguished:
- Water availability
- Water Needs
- Water balance.

2.16. Planting Patterns

Planting pattern is the most important way in planting system planning. The purpose of holding a planting system is to set the time, place, type and area of plants in the irrigation area. The purpose of the planting system is to utilize the irrigation water supply as effectively and efficiently as possible so that the plants can grow well [6].

Based on the understanding of planting system as above there are four factors that must be regulated, namely:

a) Early Planting
b) Types of Plants
c) Area
d) Denit available
e) Types of Planting Patterns, Determination of the type of cropping patterns adapted to the available water discharge at each planting season.

Types of cropping patterns of an irrigation area can be classified into:

a) Rice
b) Rice - Rice - Palawija
c) Rice - Palawija – Palawija
3. Research Method

3.1. Location

Location of the study was conducted in the Solok Regency Irrigation Area, geographically Solok Regency is between 010 20 ’27 ’ and 010 2’ 39 ” south latitude and 1000 33 ’43’ East Longitude. For more details about the location of work presented on the figure 9.

![Fig. 9 Maps of Solok Regency](image)

Rainfall data used is rainfall data in 2009 - 2018, in the rainfall analysis using the Thiessen method where the watershed area is 3,738 ha and the area of influence is based on 3 observation stations:
1. Kayu Aro Station
2. Teluk Bayur Maritime Methodology Station
3. Padang Panjang Geophysical Station

![Fig. 10 Image: Map of Area of Influence](image)

3.2. Steps of Research

The steps - the workmanship of the research can be seen in figure 11.
4. Result and Discussion

4.1. Calculating Potential Evapotranspiration (ETo)

Plant evapotranspiration is a crop water requirement needed for plant growth, which is the result of evapotranspiration with plant coefficients. The value of this evapotranspiration is to estimate the water requirements for paddy fields.

From using the formula above we get the Evapotranspiration value in figure 12.
4.2. Mainstay Debit Calculation

The mainstay discharge is generally analyzed as an average flow of a 10-year period taking into account the water needed from the downstream river taking to determine the paddy fields that can be drained.

![Debit Graph](image1)

**Fig. 13. Debit Graph**

From the figure 13, it can be seen that the maximum reliable discharge occurs in April of the 1st Week with Q80 of 10.41 Liters / sec / hectare and Q50 of 6.55 Liters / sec / hectare, while the minimum mainstay discharge occurs in December with Q80 was 3.93 liters / second / hectare and Q50 was 2.46 liters / second / hectare.

4.3. Effective Rainfall

The rainfall data used is semi-monthly average rainfall data. Design rain with probabilities R50 and R80 can be determined by limiting the ranking of monthly rainfall amounts from the smallest data to the biggest data based on annual rainfall.

4.4. Calculation of average rainfall data in this study uses theissen method

| Tahun | Januari Jumlah | Februari Jumlah | Maret Jumlah | April Jumlah | Mei Jumlah | Juni Jumlah |
|-------|----------------|-----------------|--------------|--------------|------------|------------|
| 2018  | 28,488         | 2016 35,394     | 2017 105,000 | 2014 157,955 | 2015 43,409 | 2015 56,986 |
| 2015  | 85,939         | 2014 54,505     | 2012 107,910 | 2017 164,966 | 2011 85,773 | 2012 79,385 |
| 2012  | 99,346         | 2015 117,096    | 2015 127,845 | 2009 178,295 | 2009 88,258 | 2014 96,904 |
| 2011  | 156,286        | 2011 119,013    | 2014 160,735 | 2015 178,728 | 2013 98,037 | 2013 99,961 |
| 2017  | 202,402        | 2009 119,644    | 2016 211,594 | 2011 192,383 | 2016 150,387 | 2009 125,931 |
| 2015  | 226,446        | 2018 201,701    | 2013 296,722 | 2012 256,523 | 2010 209,081 | 2018 151,558 |
| 2014  | 233,585        | 2012 262,769    | 2018 299,647 | 2018 258,174 | 2017 243,161 | 2010 166,354 |
| 2009  | 244,303        | 2013 293,488    | 2009 333,723 | 2016 267,710 | 2014 284,760 | 2016 175,556 |
| 2010  | 284,998        | 2012 345,409    | 2011 351,363 | 2010 280,055 | 2018 418,881 | 2017 177,257 |
| 2011  | 226,446        | 2013 243,255    | 2016 142,366 | 2017 149,890 | 2012 256,523 | 2011 112,377 |
| 2012  | 233,585        | 2010 183,160    | 2011 243,504 | 2012 178,019 | 2010 211,388 | 2012 232,716 |
| 2013  | 243,255        | 2012 191,889    | 2010 256,552 | 2011 276,872 | 2013 308,044 | 2012 287,673 |
| 2014  | 258,750        | 2011 260,755    | 2012 309,922 | 2013 267,673 | 2010 361,327 | 2017 180,434 |
| 2015  | 262,536        | 2010 243,504    | 2012 260,755 | 2012 287,673 | 2013 308,044 | 2017 180,434 |
| 2016  | 99,912         | 2014 180,097    | 2010 260,755 | 2012 287,673 | 2013 308,044 | 2017 180,434 |
| 2017  | 183,453        | 2010 183,160    | 2011 260,755 | 2012 287,673 | 2013 308,044 | 2017 180,434 |
| 2018  | 194,750        | 2011 191,889    | 2009 250,424 | 2017 339,957 | 2013 308,044 | 2017 180,434 |
| 2019  | 243,255        | 2009 207,415    | 2010 262,536 | 2018 424,927 | 2013 361,327 | 2018 361,327 |
| 2020  | 276,177        | 2014 339,597    | 2013 308,044 | 2017 361,327 | 2017 361,327 | 2018 361,327 |
| 2021  | 311,828        | 2013 308,044    | 2014 339,597 | 2017 361,327 | 2017 361,327 | 2018 361,327 |
| 2022  | 339,597        | 2012 308,044    | 2015 308,044 | 2017 361,327 | 2017 361,327 | 2018 361,327 |
| 2023  | 361,327        | 2011 308,044    | 2016 308,044 | 2017 361,327 | 2017 361,327 | 2018 361,327 |

**Fig. 14. Data Ranking Table Monthly rainfall amounts from the smallest data to the biggest data in 2009.**
After obtaining the rainfall value data from the smallest to the largest value, then the data is presented in the semi-monthly rainfall data, as shown in the figure 15.

### Table Effective Rainfall Data (Re) (in Indonesia)

| Bulan   | R80 | R50 | Jumlah | R80 Efektif (R80/JH) | R50 Efektif (R50/JH) | Re Padi (R80 x 0,7) | Re Palawija (R80 x 0,5) |
|---------|-----|-----|--------|----------------------|----------------------|----------------------|------------------------|
| Jan     | 50,46 | 157,27 | 71,69 | 27,26 | 15,50 | 3,26 | 10,15 | 4,63 | 1,78 | 2,28 | 7,10 | 2,31 | 0,89 |
| Feb     | 100,15 | 50,35 | 42,09 | 75,01 | 14,00 | 7,15 | 3,60 | 5,01 | 5,36 | 5,01 | 2,52 | 1,50 | 2,68 |
| Mar     | 131,75 | 90,04 | 67,57 | 60,28 | 15,50 | 8,50 | 5,81 | 4,36 | 3,89 | 5,95 | 4,07 | 2,18 | 1,94 |
| Apr     | 80,29 | 129,49 | 71,26 | 107,03 | 15,00 | 5,35 | 8,63 | 4,75 | 7,14 | 3,75 | 6,04 | 2,38 | 3,57 |
| Mei     | 55,64 | 93,49 | 76,30 | 20,60 | 15,00 | 3,71 | 6,23 | 5,09 | 1,37 | 2,60 | 4,36 | 2,54 | 0,69 |
| Jun     | 76,82 | 23,09 | 45,32 | 19,78 | 15,50 | 4,96 | 1,49 | 2,92 | 1,28 | 3,47 | 1,04 | 1,46 | 0,64 |
| Jul     | 56,80 | 97,92 | 76,30 | 26,47 | 15,50 | 3,66 | 6,32 | 4,92 | 1,71 | 2,57 | 4,42 | 2,46 | 0,85 |
| Aug     | 133,50 | 53,61 | 59,98 | 54,17 | 15,00 | 7,57 | 3,57 | 4,00 | 3,61 | 5,30 | 2,50 | 2,00 | 1,81 |
| Sep     | 129,49 | 111,17 | 73,35 | 135,47 | 15,50 | 8,35 | 7,17 | 4,73 | 8,74 | 5,85 | 5,02 | 2,37 | 4,37 |
| Okt     | 188,44 | 87,74 | 79,37 | 151,07 | 15,00 | 12,56 | 5,85 | 5,29 | 10,07 | 8,79 | 4,09 | 2,65 | 5,04 |
| Nov     | 81,58 | 55,69 | 50,87 | 61,00 | 15,50 | 5,26 | 3,59 | 3,28 | 3,94 | 3,68 | 2,51 | 1,64 | 1,97 |
| Des     | 209,78 | 1,78 | 3,47 | 30,50 | 15,50 | 1,14 | 0,89 | 5,02 | 2,50 | 2,00 | 1,81 | 2,37 | 4,37 |

Fig. 15. Ranking data table of Half-Monthly Rainfall in 2009 – 2018 (in Indonesia)

Fig. 16. Table Effective Rainfall Data (Re) (in Indonesia)
The biggest effective rainfall for rice plants occurred in November the first week, and the lowest was in July the second week, while for the crops crops the biggest effective rainfall occurred in November the second week, and the lowest occurred in November May 1st week.

4.5. Water Needs For Consumptive Plants (ETc)

Plant consumptive needs are the amount of water used by plants for the photosynthesis process of these plants. The need for plants can be known by calculating the value of evapotranspiration which is influenced by plant coefficients (plant type, plant age and climatology).

So we get the value of water demand in the intake channel in March M-1 of 0.763 l / sec / ha, and for further calculations it is presented in the form of a table below.

4.6. Water Balance

Water balance calculation is carried out to check whether the available water is sufficient to meet the irrigation water requirements in the project concerned. Calculations are based on weekly or semi-monthly periods.

Three main elements are distinguished:
- Water availability
- Water Needs
- Water balance.

4.7. Planning Patterns

In this study, 12 alternatives were used for the simulation of cropping patterns, out of the 12 alternatives the 7th alternative was chosen as the best and most efficient cropping pattern, with the following considerations.
From the conclusion of the Mainstay Debit, the PADI-PADI-PALAWIJA Planting Pattern is adopted, the PADI crop starts planting in February-May, in June the Planting Process (BERO) is not carried out, after that the PADI Planting is carried out again from July - October, on November - January security PALAWIJA.

PADI crops were taken in February and July because in that month the availability of water in the Irrigation District of Solok was very large, as evidenced by the results of the Mainstay Debit, and the PADI plants also needed a lot of water for land preparation (LP), so that the water could be used maximally.

5. Conclusion

The most efficient and optimal planting pattern obtained is PADI-PADI-CORN with large irrigation water requirements in tertiary plots (NFR tertiary plots) ranging from 0 - 1,546 ltr / sec / ha with a maximum of 1,546 ltr / sec / ha in September II, whereas Irrigation water demand in the intake (DR intake) ranges from 0 to 2,378 ltr sec / ha with a maximum of 2,378 ltr / sec / ha in September II. The mainstay discharge available in the Pauh Tinggi Irrigation Network Planning is very abundant with the mainstay discharge (Q80) for irrigation, the maximum mainstay discharge (Q80) occurs in April I with 10,482 ltr / sec / ha and minimum in December II with 3,930 ltr / sec / ha. Based on the mainstay discharge results above it can be stated that the water balance / water balance between the mainstay discharge Q80 and the need for irrigation water experienced a large surplus.

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