Available online at http://jurnal.ahmar.id/index.php/asci

Journal of Applied Science, Engineering, Technology, and Education

ISSN 2685-0591 (Online)

Journal of Applied Science, Engineering, Technology, and Education Vol. 1 No. 2 (2019)
https://doi.org/10.35877/454RI.asci1138

Planning Optimization Planning Irigation Area of Solok Sumatera West Regency

Acep Hidayat[a,*], Deri Ferdiana[b]

[a]Faculty of Engineering, University Mercu Buana Jakarta, Indonesia, acep_hdyt75@yahoo.com
[b]Faculty of Engineering, University Mercu Buana Jakarta, Indonesia

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.

Keywords: Planting pattern, Solok Regency irrigation network, reliable discharge.

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

* Corresponding author.
E-mail address: acep_hdyt75@yahoo.com (Acep Hidayat)

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 pembuang terpisah	Saluran irigasi dan pembuang tidak sepenuhnya terpisah	Saluran irigasi dan pembuang jadi satu
4	Petak tersier	Dikembangkan sepenuhnya	Belum dikembangkan atau densitas bangunan tersier jarang	Belum ada jaringan terpisah yang dikembangkan
5	Efisiensi secara keseluruhan	Tinggi 50 – 60 % (Ancar-ancar)	Sedang 40 – 50% (Ancar-ancar)	Kurang < 40% (Ancar-ancar
6	Ukuran	Tak ada batasan	Sampai 2.000 ha	Tak lebih dari 500 ha
7	Jalan Usaha Tani	Ada ke seluruh areal	Hanya sebagian areal	Cenderung tidak ada
8	Kondisi O & P	- Ada instansi yang menangani - Dilaksanakan teratur	Belum teratur	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]

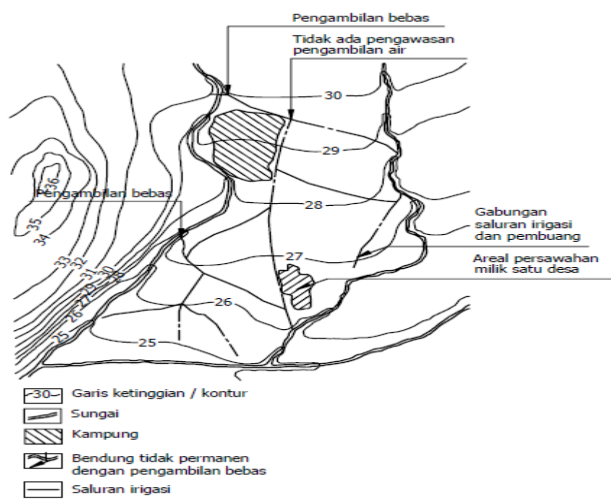

Fig. 2 Simple Irrigation Networks (in Indonesia)
(Source:KP-01 Irrigation Planning Standards)

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]

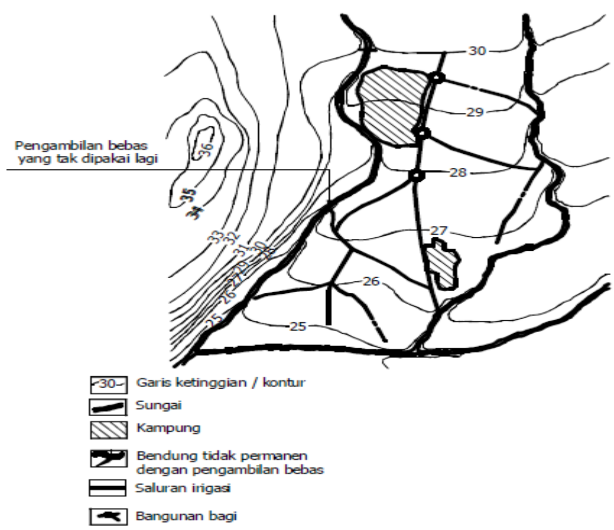

Fig. 3 Semiteknis Irrigation Network (in Indonesia)
(Source:KP-01 Irrigation Planning Standards)

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]

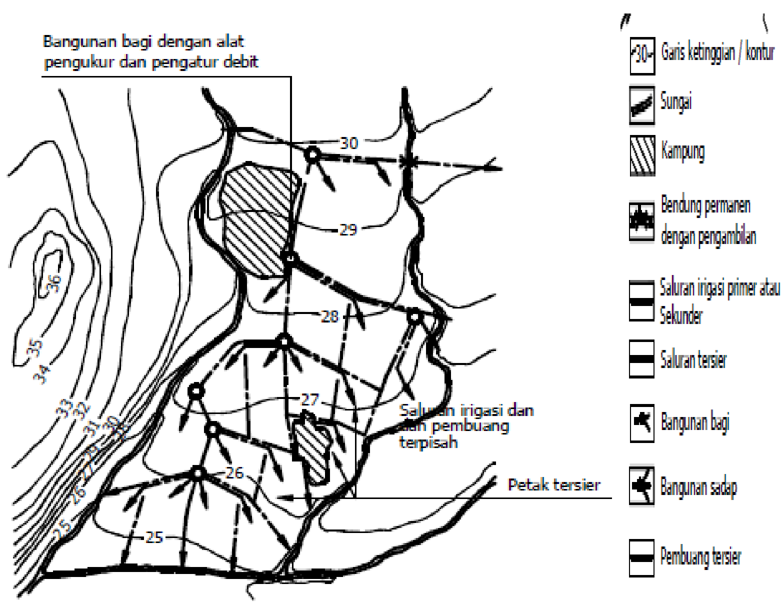

Fig. 4 Technical Irrigation Networks (in Indonesia)
(Source:KP-01 Irrigation Planning Standards)

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:

$e_s = 611 \exp\left(\frac{17{,}27\,T}{237{,}3+T}\right)$

$e_d = e_s\, r$

$E = B\,(e_s - e_d)$

$B = \frac{0{,}102\,u_2}{\left(\ln\left(\frac{z_2}{Z_0}\right)\right)^2}$

$L_n = \sigma T^4\,(0{,}56 - 0{,}092\sqrt{ed})\,(0{,}1 + 0{,}9\,\frac{n}{N})$

$S_t = S_0\,(a + (b \times n/12{,}1))$

$S_n = S_t\,(1 - \alpha)$

$R_n = S_n - L_n$

$l_v = 597{,}3 - 0{,}56\,T$

$$E_n = \frac{Rn}{\rho w\ lv}$$

$$ET_0 = \frac{\beta En + E}{\beta + 1}$$

with:

A = reflection coefficient (albedo)
B = temperature function
Σ = Stevan-Boltzman constant (1.17. 10-7 cal / cm2 / K4 / day)
Pw = density of water (1 gr / cm3)
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 / cm2 / 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 / cm2 / 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 β value based on temperature

T (°C)	β = Δ/ γ
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 α value (albedo)

Type of face	Albedo (α)
Open water	0,05 - 0,15
Rock	0,12 - 0,15
Sand	0,10 - 0,20
Dry soil	0,14

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

Lintang	Jan	Feb	Mar	Apr	Mei	Jun	Jul	Agu	Sep	Okt	Nov	Des
90° LS	0	0	40	470	900	1085	1010	670	170	0	0	0
80° LS	0	0	125	480	890	1075	995	660	255	25	0	0
70° LS	0	70	275	565	855	1025	945	685	385	145	15	0
60° LS	90	215	425	670	890	1000	945	770	510	285	120	60
50° LS	225	360	555	750	930	1010	970	830	640	435	265	190
40° LS	380	505	675	845	965	1020	985	895	740	565	415	335
30° LS	520	630	775	895	975	1000	990	925	820	685	560	490
20° LS	660	750	850	920	960	965	960	935	875	785	685	630
10° LS	780	840	900	925	915	900	905	915	905	865	800	760
0°	885	915	925	900	850	820	830	870	905	910	890	875
10° LU	965	960	915	840	755	710	730	795	875	935	955	960
20° LU	1020	975	88	765	650	590	615	705	820	930	1000	1025
30° LU	1050	965	830	665	525	460	480	595	750	900	1020	1065
40° LU	1055	925	740	545	390	315	345	465	650	840	995	1080
50° LU	1035	865	640	415	250	180	205	325	525	760	975	1075
60° LU	1000	785	510	280	110	55	75	190	390	660	920	1060
70° LU	1000	695	375	130	10	0	0	55	250	550	885	1090
80° LU	1035	645	225	15	0	0	0	0	100	450	905	1140
90° LU	1055	660	135	0	0	0	0	0	15	440	920	1160

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 R_n

measuring station will be located on a certain polygon An. By calculating the area ratio for each station of magnitude = 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:

$$d = \frac{A1.d1 + A2.d2 + A3.d3 \ldots.. + An.dn}{A} = \sum \frac{Ai.di}{A}$$

with:

A	= Area (km^2)
D	= Height of average area rainfall (mm/day)
d1, d2, d3, ..., dn	= High rainfall in the post (mm/day)
A1, A2, A3, ..., An	= Area of influence (km^2)
1,2,3, …, 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:

$$R80 = \frac{n}{5} + 1$$

with:

n	=	Rainfall observation period (year)
R80	=	Mainstay rainfall of plants with the possibility of rain that is smaller than R80 has a probability of 20%, while those greater or equal to R80 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 (Kc)

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].

Umur tanaman			RH_{min} < 70%		RH_{min} < 20%	
12 bulan	24 bulan	Tahap pertumbuhan	angin kecil sampai sedang	angin kencang	angin kecil sampai sedang	angin kencang
0 – 1	0 – 2,5	saat tanam sampai 0,25 rimbun *)	55	.6	.4	.45
1 – 2	2,5 – 3,5	0,25 – 0,5 rimbun	.8	.85	.75	.8
2 – 2,5	3,5 – 4,5	0,5 – 0,75 rimbun	.9	.95	.95	1,0
2,5 – 4	4,5 – 6	0,75 sampai rimbun	1,0	1,1	1,1	1,2
4 – 10	6 – 17	penggunaan air puncak	1,05	1,15	1,25	1,3
10 – 11	17– 22	awal berbunga	.8	.85	.95	1,05
11 – 12	22 – 24	menjadi masak	.6	.65	.7	.75

Fig. 6 The table of price of paddy crop coefficient (in Indonesia)

Bulan	Nedeco/ Prosida		FAO	
	Varietas[2] Biasa	Varietas[3] Unggul	Varietas biasa	Variaetas Unggul
0,5	1,20	1,20	1,10	1,10
1	1,20	1,27	1,10	1,10
1,5	1,32	1,33	1,10	1,05
2	1,40	1,30	1,10	1,05
2,5	1,35	1,30	1,10	0,95
3	1,24	0	1,05	0
3,5	1,12		0,95	
4	0[4]		0	

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

Tanaman	Jangka tumbuh/ hari	½ bulan No.	1	2	3	4	5	6	7	8	9	10	11	12	13
Kedelai	85		0,5	0,75	1,0	1,0	0,82	0,45*							
Jagung	80		0,5	0,59	0,96	1,05	1,02	0,95*							
Kacang tanah	130		0,5	0,51	0,66	0,85	0,95	0,95	0,95	0,55	0,55*				
Bawang	70		0,5	0,51	0,69	0,90	0,95*								
Buncis	75		0,5	0,64	0,89	0,95	0,88								
Kapas	195		0,5	0,5	0,58	0,75	0,91	1,04	1,05	1,05	1,05	0,78	0,65	0,65	0,65

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

2.8. Effective Rainfall

Effective rainfall is determined by the amount of R_{80} 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 R_{80} has a possibility of only 20% [1].

When stated with the formula is as follows:

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

with:

R80 = 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].

$$Re_{padi} = \frac{R_{80}\ x\ 0.7}{Period\ of\ observation}$$

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

$$Re_{palawija} = \frac{R_{80}\ x\ 0.5}{Period\ of\ observation}$$

with:
Re (rice) = Effective rainfall for rice rice field (mm / hr)
Re (Palawija) = Effective rainfall for Palawija (mm / hr)
R80 = 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:

$$M = E_0 + P = 1{,}1\ ET_0 + P$$

$$Pd = \frac{Me^k}{e^k - 1}$$

with:
e = Constants (2.71828)
Pd = 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 fieldssaturated M = Eo + P (mm / day)
Eo = Open water evaporation taken 1.1 Eto during land preparation (mm / day)
P = Percolation
k = 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:

$$Etc = Kc \times Eto$$

Information :
Etc = Evapotranspiration of plants (mm / day)
Eto = Evapotranspiration of reference plants (mm / day)
Kc = 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:
ef = tertiary tissue efficiency 60% x efficiency secondary tissue 90% x 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:

$$DR = NFR/(ef \times 8{,}64)$$

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.

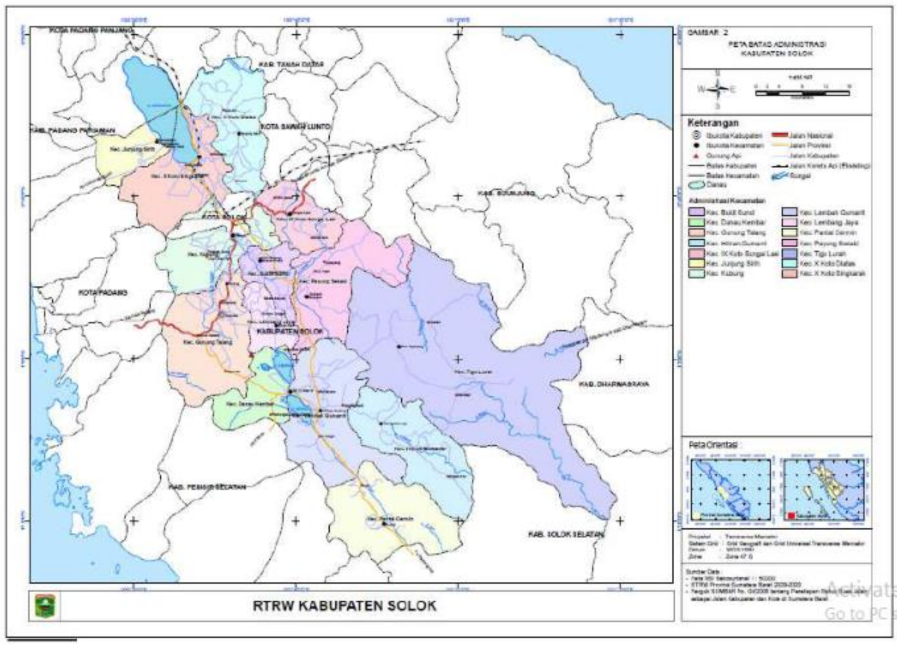

Fig. 9 Maps of Solok Regency

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

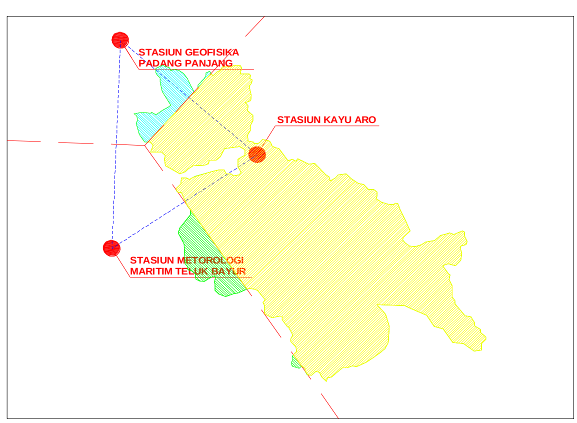

Fig. 10 Image: Map of Area of Influence

3.2. Steps of Research

The steps - the workmanship of the research can be seen in figure 11.

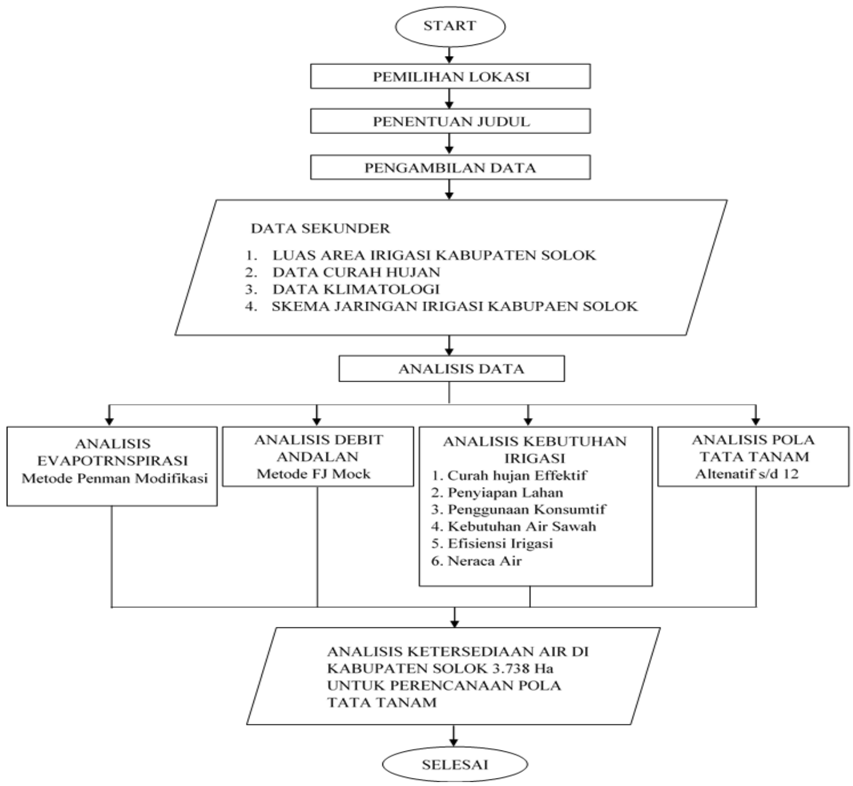

Fig. 11 Flowchart of research study (in Indonesia)

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.

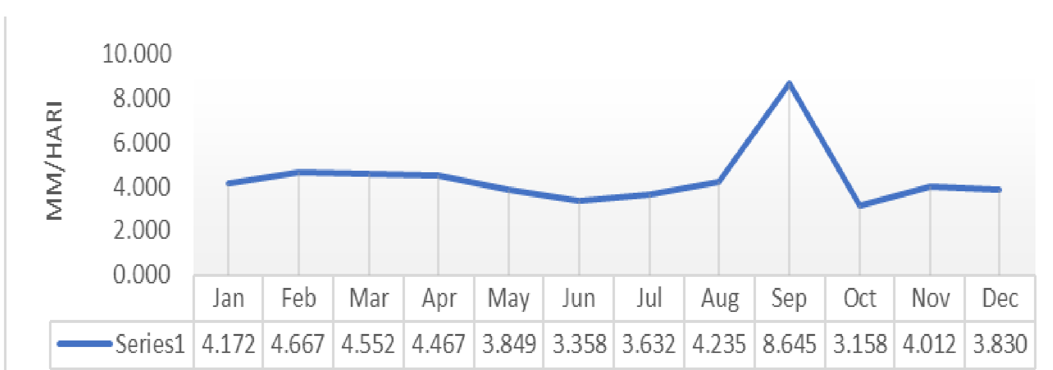

Fig. 12. Evapotranspiration Table (ETo) (in Indonesia)

Source: Data Processing

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.

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 to the largest data based on annual rainfall.

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

Januari		Februari		Maret		April		Mei		Juni	
Tahun	**Jumlah**	**Tahun**	**Jumlah**	**Tahun**	**Jumlah**	**Tahun**	**Jumlah**	**Tahun**	**Jumlah**	**Tahun**	**Jumlah**
2018	28,488	2016	35,394	2017	105,000	2014	157,935	2015	43,409	2015	56,986
2015	85,939	2014	54,505	2012	107,910	2017	164,596	2011	85,773	2012	79,385
2012	99,346	2015	117,096	2015	127,845	2009	178,295	2009	88,258	2014	96,904
2016	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
2013	207,735	2010	150,494	2010	221,791	2013	209,786	2012	161,972	2011	149,129
2011	226,446	2018	201,701	2013	296,722	2012	256,523	2010	209,081	2018	151,558
2014	233,058	2017	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

Juli		Agustus		September		Oktober		November		Desember	
Tahun	**Jumlah**	**Tahun**	**Jumlah**	**Tahun**	**Jumlah**	**Tahun**	**Jumlah**	**Tahun**	**Jumlah**	**Tahun**	**Jumlah**
2016	56,892	2015	63,215	2012	74,998	2015	107,257	2015	88,472	2015	94,891
2017	64,560	2018	96,147	2015	103,164	2014	123,195	2016	179,671	2009	103,982
2015	65,093	2017	102,766	2014	114,154	2013	208,821	2009	230,437	2011	111,874
2011	76,773	2013	113,655	2016	126,840	2010	211,388	2012	232,716	2010	112,377
2009	97,368	2016	142,366	2017	149,890	2016	220,454	2011	245,957	2016	131,074
2018	99,912	2014	154,719	2013	167,104	2009	240,661	2018	276,177	2014	137,266
2014	142,009	2012	180,097	2018	210,361	2011	250,715	2010	279,092	2012	178,019
2010	183,453	2010	183,160	2011	243,504	2012	260,755	2017	287,673	2017	180,434
2012	194,750	2011	191,889	2009	250,424	2017	311,828	2014	339,597	2013	308,044
2013	243,255	2009	207,415	2010	262,536	2018	424,927	2013	404,462	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.

Tahun	Jan		Feb		Mar		Apr		Mei		Jun	
	I	II	I	II	I	II	I	II	I	II	I	II
2009	58,84	185,46	21,16	98,48	238,37	95,36	71,26	107,03	17,61	70,64	43,73	82,20
2010	158,40	126,60	100,15	50,35	131,75	90,04	194,38	85,67	66,28	142,80	43,25	123,10
2011	52,05	174,40	28,46	90,55	255,77	95,59	68,41	123,97	7,45	78,32	55,64	93,49
2012	71,69	27,66	223,59	121,82	60,71	47,20	143,23	113,29	79,62	82,35	33,31	46,07
2013	50,46	157,27	226,31	67,18	56,78	239,94	80,29	129,49	54,14	43,90	54,89	45,07
2014	174,60	58,46	45,34	9,16	75,90	84,83	60,56	97,38	126,33	158,43	76,30	20,60
2015	24,89	61,05	42,09	75,01	67,57	60,28	53,26	125,46	26,35	17,06	36,55	20,44
2016	33,75	122,54	12,98	22,41	89,73	121,86	120,02	147,69	25,00	125,38	127,94	47,62
2017	135,91	66,49	225,05	37,72	27,42	77,58	72,45	92,15	33,38	209,78	145,14	32,12
2018	8,59	19,89	121,18	80,53	198,60	101,04	173,28	84,90	241,35	177,53	3,92	147,64

Tahun	Jul		Agu		Sep		Okt		Nov		Des	
	I	II	I	II	I	II	I	II	I	II	I	II
2009	68,61	28,76	66,85	140,57	181,08	69,34	129,49	111,17	79,37	151,07	40,70	63,28
2010	89,63	93,83	88,56	94,60	98,33	164,21	143,76	67,62	102,97	176,12	46,90	65,48
2011	51,05	25,72	60,12	131,77	180,41	63,10	131,77	118,95	97,13	148,82	50,87	61,00
2012	124,50	70,25	27,39	152,70	32,95	42,05	64,90	195,85	120,36	112,36	120,25	57,77
2013	128,91	114,34	24,73	88,92	113,50	53,61	73,35	135,47	282,61	121,85	120,42	187,62
2014	42,83	99,17	56,80	97,92	59,98	54,17	58,17	65,03	99,27	240,32	81,58	55,69
2015	45,32	19,78	12,31	50,91	58,60	44,57	42,93	64,33	37,73	50,74	56,29	38,60
2016	20,99	35,90	55,92	86,44	31,40	95,44	115,85	104,61	121,95	57,72	49,57	81,50
2017	38,48	26,08	76,30	26,47	27,04	122,85	136,09	175,74	196,52	91,15	127,84	52,59
2018	76,82	23,09	45,97	50,18	85,02	125,34	285,12	139,80	188,44	87,74	335,56	25,76

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

No	Bulan	R80		R50		Jumlah	R80 Efektif (R80/JH)		R50 Efektif (R50/JH)		Re Padi (R80 x 0,7)		Re Palawija (R80 x 0,5)	
		I	II	I	II	Hari	I	II	I	II	I	II	I	II
1	Januari	50,46	157,27	71,69	27,66	15,50	3,26	10,15	4,63	1,78	2,28	7,10	2,31	0,89
2	Februari	100,15	50,35	42,09	75,01	14,00	7,15	3,60	3,01	5,36	5,01	2,52	1,50	2,68
3	Maret	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
4	April	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
5	Mei	79,62	82,35	17,61	70,64	15,50	5,14	5,31	1,14	4,56	3,60	3,72	0,57	2,28
6	Juni	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
7	Juli	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
8	Agustus	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
9	September	113,50	53,61	59,98	54,17	15,00	7,57	3,57	4,00	3,61	5,30	2,50	2,00	1,81
10	Oktober	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
11	November	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
12	Desember	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

Fig. 16. Table Effective Rainfall Data (Re) (in Indonesia)

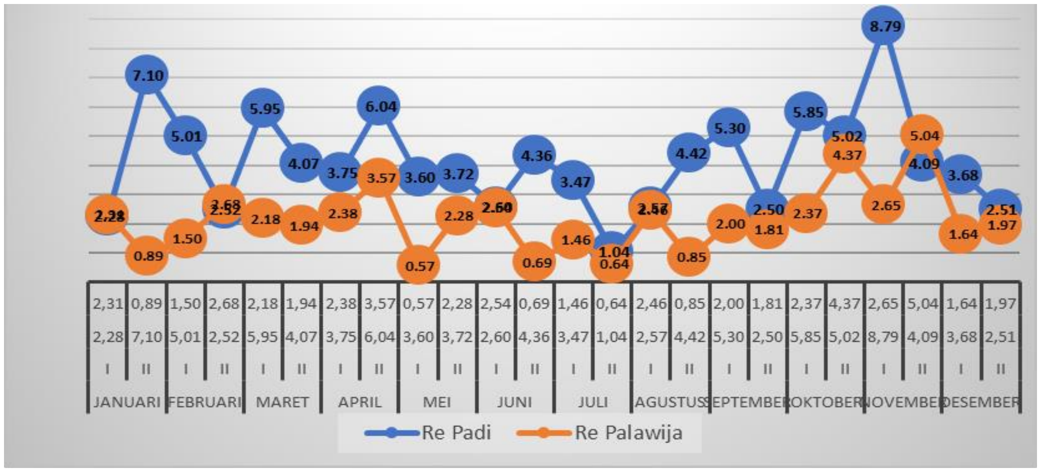

Fig. 16. The effective rainfall (in Indonesia)

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).

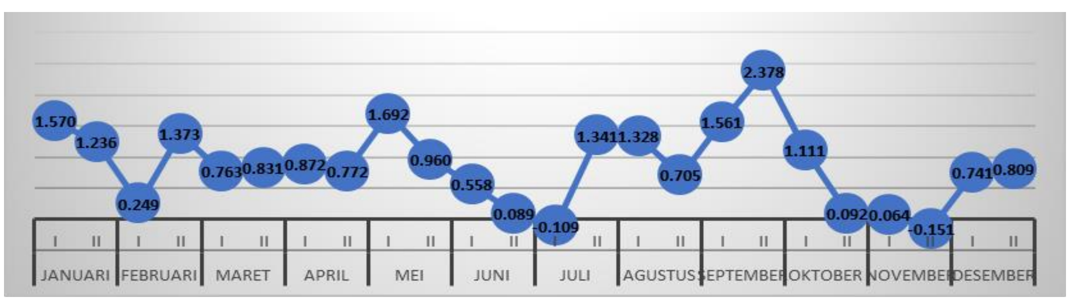

Fig. 17. The water demand in Intake (in Indonesia)

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.

References

[1] A. Priyonugroho, “Journal Of Civil And Environmental Engineering 2.3,” Analisis Kebutuhan Air Irigasi (Studi Kasus Pada Daerah Irigasi Sungai Air Keban Daerah Kabupaten Empat Lawang), 2014.
[2] Badan Pusat Statistik Kabupaten Solok, 2010.
[3] "RPIJM - Rencana Terpadu dan Program Infrastruktur Jangka Menengah Kabupaten Solok," 2014.
[4] M. Udiana, “Jurnal Teknik Sipil 1.3,” Kajian Sistem Irigasi Sprinkler di Desa Oesao Kabupaten Kupang, 2012.
[5] Triatmojo, B. (2014). Hidrologi Terapan, edisi keempat. Beta Offset, Yogyakarta.
[6] Standar Perencanaan Irigasi, Kriteria Perencanaan Bagian Jaringan Irigasi, KP-01, 2010.
[7] D. H. U. Ningsih, “Dinamik 17.2,” Metode thiessen polygon untuk ramalan sebaran curah hujan periode tertentu pada wilayah yang tidak memiliki data curah hujan, 2012.
[8] A. KAELISMA, “Kurva S Jurnal Mahasiswa,” Analisa Jaringan Irigasi pada Daerah Irigasi (DI) Tepian Buah Kabupaten Berau Kalimantan timur, 2018.
[9] P. D. H. Ardana, Analisis Kebutuhan Air Irigasi Di Daerah Irigasi (Di.) Tengkulak Mawang Pada Daerah Aliran Sungai (Das.) Petanu Di Kabupaten Gianyar, 2019.