

ACTUAL WATER AVAILABILITY AND WATER NEEDS IN IRRIGATION AREA OF RIAM KANAN IN SOUTH KALIMANTAN PROVINCE

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ABSTRACT

Management and utilization of irrigation water in Riam Kanan have a significant impact on availability system and water needs for irrigation and non irrigation (domestic, non domestic, fishery, industry and maintenance of river). This study aims at finding out the potential of water availability and water needs for irrigation and non irrigation as well as delineating the status of water balance in the irrigation area of Riam Kanan. The data used in this study were monthly meteorological data from the year 2002 to 2012, daily rainfall data of 7 stations from 2002 to 2010 in P.M. Noor Watershed and daily rainfall data of 2 stations namely BMKG Banjarbaru and SMPK Sei Tabuk from 1990 to 2012. Besides, the data of catchment area of watershed, planting area and the age of crops were also used. Mock and Nreca methods were used to count water availability to find out the 80% discharge transition in Riam Kanan irrigation area. Meanwhile, standard planning KP-01 of Department of Public Work was used to find out the water availability for irrigation and non irrigation. Water balance analysis in irrigation area of Riam Kanan by using Mock and Nreca methods, by the time the water is needed for irrigation, the water has deficit from May 2012 to September 2012 of 0.21 until 6.56 m³/sec. The results of the study showed that surplus water occurs in wet season and is not used for irrigation. Meanwhile, deficit water happens in dry season, especially for water needs from June until September.

Keywords: water, water balance, catchment area and climate

INTRODUCTION

Nowadays there has been an imbalance between water availability and water needs in the field of water services. Water availability is continuously decreasing while the demand for water is increasing. Based on Acts No. 7 of 2004 about Water Resources, to deal with an imbalance between water availability which tends to decline and water needs increase, water resources must be well managed by considering the social function, environment and economy.

Dry season is the peak of irrigation needs, while the condition of irrigation channel both primary channel and secondary channel are lacking of water. This is due to people's behavior taking water from outside the system and it gives effect to less irrigation water needs in the downstream of paddy fields which include water availability in the form of amount, quality, and regulation of water according to crop needs.

Karang Intan dam, as a source of water irrigation, can irrigate the fields through the construction of irrigation channels; those are primary, secondary, tertiary, quarter channels and door. The usage of irrigation water in Riam Kanan covers irrigation area of 10,585 Ha, which consists of three watering observer regions, namely Gudang Tangkas 3,574 Ha, Kramat Bincau 2,220 Ha and Ulin Tabuk 4,791 Ha. Meanwhile, the use of non-irrigation

water such as taps (PDAM) Intan Banjar Banjarbaru 500 l/sec, and taps (PDAM) Bandarmasih Banjarmasin 1,500 l/sec in addition to fish farming and industry.

The usage of non-irrigation water affects the main requirement of irrigation function that is to suffice water needs for irrigation and its usage including the following:

1. In 1995, new water users appeared, in the form of raw water supply for the taps (PDAM) in Banjarbaru city and Banjarmasin city, by directly taking water from the primary channel so that it cannot be measured and regulated; this was not wise.
2. A similar taking for variety of usages until 2012 covered an area of 841.7 Ha, while the area of Minapolitan Kab. Banjar is 6,406 Ha with potential for fish ponds covering 1,195 Ha (Fisheries Office of Banjar District, 2012).

The location of field irrigated which has been planned partly changes into settlements which cause a reduction of agricultural areas.

This study discusses the issue of water supply and water needs for domestic and non-domestic use. The effort of agricultural land intensification is determined primarily by the balance-availability of agricultural water needs. For areas that have the balance of positive water availability-needs, it is predicted that the region will have a chance to increase high cropping index. Thus, the results of this study can be used as guidance for policy makers in formulating plans to increase the productivity of food crops, especially rice through crop index (IP 300).

METHODS

Area of Study

The object of this study was irrigation area in Riam Kanan which is located in Banjar district, Banjarbaru city, and Banjarmasin city. Geographically, Karang Intan dam is located in 3027'14" SL. (South Latitude) and 114057'14" EL. (East Longitude) and the location of the rice fields downstream is in Tabuk Sei village which lies on 3020'0" SL. and 114038'12" EL. (Map 1). The topography, in irrigated areas of Riam Kanan at height of 0.963-10.408 m MSL, is varied from flat to hilly. Geological conditions, such as the primary rocks are pre-tertiary sediment formations, pluton rocks and alkaline rocks. The profiles of paddy soil in the area of study consist of two kinds, namely (i) Ground Water Gley Rice Soil which is paddy soil with shallow ground water or flooded areas which are located in Sei Tabuk towards Aluh-Aluh, and (ii) Intermediate Gley-like rice soil which is paddy soil with a depth of intermediate ground water which is located in West Martapura district. In the taxonomy of soil in the study area, it is reflected in subgroup epiaquic from great group in Ultisol and Oxisol order in areas with high rainfall that experience seasonal inundation (seasonal superficial waterlogging). Based on the semi-detailed soil maps, the soil in the area of study is included into Fibric, Dyxic, and Terric Tropofibrists.

The problems that occurred in the area of irrigation in Riam Kanan is the excess of water in rainy season so that the soil cannot be planted with paddy and water shortage happens in the dry season so that production of paddy is less.

The objectives of this study are to find out the potential of water availability and needs for irrigation and non-irrigation as well as to delineate the areas of irrigation water balance status in Riam Kanan.

The result to be achieved is to know the condition of water in irrigation area of Riam Kanan, whether it is surplus or deficit for irrigation and non-irrigation purposes.

Data Collection

The activities carried out in this study first began with the preparation of research including research studies, field equipment, and material research. Then, identification and surveys were conducted as well as primary and secondary data collection. The steps in collecting data were as follows:

1. Climate data was used to search for evapotranspiration with Penman Monteith method/CropWatt 8.0.
2. Hydrological data was used to calculate the availability and irrigation water needs.
3. Ground data was used to calculate irrigation water needs with CropWatt 8.0.
4. Crop data was used to determine the cropping pattern and water needs of plants.
5. Field data was used to determine the irrigated and non-irrigated areas, and the area of early planting.
6. Building and irrigation network was used to determine the efficiency of irrigation.

Water Needs

Mock Method

The data used in this study were the daily rainfall data, temperature, wind speed, humidity, period of sunshine, and the coverage area. The calculation of Riam Kanan watershed discharge with Mock method used the following formula:

Water Balance on the Land Surface

Water balance on the land surface is calculated based on the amount of monthly precipitation minus limited evapotranspiration of monthly average thus obtained the equation:

$$\Delta S = P - Et$$

Where

ΔS = changes of soil water content (soil storage).

ΔS = the value is positive when $P > Et$, the water goes into the ground.

ΔS = the value is negative when $P < Et$, some ground water will come out so that it becomes deficit.

Ground Water Storage

The value of run off and ground water depend on the water balance and the ground condition. The data required are:

Infiltration coefficient = I , is taken 0.2-0.5

Recession factor of ground water flow = k , is taken 0.4-0.7

Equation:

$$I_n = \text{Water Surplus} \times I$$

$$V_n = k \cdot V_{(n-1)} + 0,5(I+k)I_n$$

$$DV_n = V_n - V_{n-1}$$

Where

I_n = volume of water infiltration which gets into the soil

V_n = volume of ground water

A= volume of the storage per month

V_n = changes of the volume of ground water in the n-month

$V_{(n-1)}$ = volume of ground water month (n-1)

I= infiltration coefficient

River Flow

Interflow = Infiltration – Volume of ground water (mm)

Direct run off = Water surplus –infiltration (mm)

Base flow = River flow which are always available throughout the year (m^3/sec)

Run off = interflow + Direct run off + Base flow (m^3/sec)

Nreca Method

NRECA model (National Rural Electric Cooperative Associatori) was developed by Norman H. Crawford (USA) in 1985. This model is a deterministic conception model. To interpret the phenomenon of its physical processes, semi-empirical equations and formulas are used, with the water balance equation as follows:

$$Ro = P - AE \pm \Delta S$$

Where

RO= surface flow (mm).

P= rainfall (mm).

ΔE = actual evapotranspiration (mm).

ΔS = storage change (mm).

The total of river flow is calculated by the following equation.

$$Q = (GF + DRF)A \quad (m^3/s)$$

Where

A = width of watershed/DAS (km^2)

DRF = direct flow (mm)

= $excm (1 - PSUB)$, with $excm$

= excess of humidity

$Excm = exrat \times (P - AET)$

GF = ground water flow (mm)

= $GWF \times (PSUB \times excm = GWS)$

Exrat = excess of humidity ratio

= $0.5 \times (1 + \tanh((Sr - 1) / 0.52))$, if $Sr > 0$

= 0, if $Sr < 0$

$Sr = catch\ rate = SMS/NOM$

P = monthly rainfall (mm)

AET = actual evapotranspiration

= $CROPF \times PET$, if $P/PET > 1$ or $Sr > 2$

= $(kl \times PET) \times CROPF$, if $P/PET < 1$ or $Sr < 2$

$kl = (P/PET) \times (1 - 0.5 Sr) + 0.5 Sr$

CROPF = crop factor

Irrigation Water Needs

Irrigation water needs is calculated by using the following formula:

$$KAI = \frac{Etc + IR + WLR + P - Re}{IE} \times A$$

Where

KAI = irrigation water needs in litre/second

Etc = consumptive water needs, in mm/day

IR = irrigation water needs of paddy field level, in mm/day

WLR = water needs to replace the water layer, in mm/day

P = percolation, in mm/day

Re = effective rainfall, in mm/day

IE = irrigation efficiency, in %

A = irrigation area, in ha

Consumptive Water Needs

Consumptive water needs is calculated by the following equation:

$$Etc = K \times Eto$$

Etc = Consumptive water needs (mm/day)

Eto = Evapotranspiration, (mm/day)

K = Plant coefficient, the proportion for prime varieties (FAO) in month 0.5 = 1.10, month 1.0 = 1.10, month 1.5 = 1.05, month 2.0 = 1.05, month 2.5 = 0.95 and month 3.0 = 0

Irrigation water needs in Paddy Field Level

Irrigation water needs for land preparation by Van de Goor and Zijlstra's formula is as follows:

$$IR = M(e^k / (e^k - 1))$$

Where

IR = irrigation water needs in paddy field level (mm/day)

M = water needs to replace water loss due to evaporation and percolation in fields that had been saturated = (Eo + P)

P = percolation (mm/day)

Eo = open water evaporation = (1.1 x Eto) during land preparation (mm/day)

k = M (T/S)

T = the duration of land preparation (day)

S = water needs for saturation plus layers of water 50 mm, that is 200 mm + 50 mm = 250 mm

e = coefficient

Water Needs to Replace Water Layers (WLR)

Water needs to replace water layers is established based on Irrigation Planning Standards 1986, KP-01 in the amount of 50 mm/month (or 3.3 mm/day for ½ month), for a month and two months after transplantation.

Percolation

Percolation rate depends on soil characteristics, and depends on the activities of the land usage or soil cultivation, the amount ranges between 1-3 mm/day.

Effective Rainfall

The amount of effective rainfall for paddy is calculated by the following equation:

$$Re = 0.7 \times R_{80}/15$$

Re= effective rainfall (mm/day)

R80= rainfall which may not be used

Non Irrigation Water Needs***Domestic Water Needs***

The amount of domestic water needs is calculated based on the number of residents in the study site; those are Banjar District, Banjarbaru City and Banjarmasin City.

Non Domestic Water Needs

Non domestic water needs include the need for water supply such as government offices, social, hotels, hospitals. The amount of non domestic water needs is 30 litres/person/day multiplied by the number of population.

Industrial Water Needs

Industrial water needs is based on water usage in the industry which include water as raw material in industrial processes, flushing out the waste and the amount of labor. To fulfill the water needs, 10% of the domestic water consumption is determined.

Water Needs for Fisheries

Water needs for fisheries include filling the pond at the beginning of planting fish seeds and replacing water which are determined 7 mm/day/ha.

Water Needs for River Preservation

The amount of water needs for the river/channel preservation is 330 litres/capita/day.

Total of Non Irrigation Water Needs

The total of non irrigation water needs is calculated based on population and per capita of water needs. The calculation of water needs for household is based on standards issued by Irrigation Pulitbang Department of Public Works. Water needs for industry is calculated as much as 10% of domestic water consumption while to maintain the river is calculated by multiplying the number of urban population with water needs for maintenance/flushing per capita. Analysis of total water demand is calculated by this formula:

$$Q_{\text{total}} = Q_{\text{irrigation}} + Q_{\text{domestic}} + Q_{\text{non domestic}} + Q_{\text{industry}} + Q_{\text{fishery}} + Q_{\text{maintenance river}}$$

Water Balance

Water balance is calculated based on the availability and needs of irrigation and non-irrigation water. The analysis of the water balance is done by using calculation of water availability and water needs through the process as in Figure 1: flowchart of Water Irrigation Management and Usage in Riam Kanan. The calculation components include evapotranspiration, water discharge, irrigation and non-irrigation water needs.

RESULTS AND DISCUSSION

Evapotranspiration

Evapotranspiration (Eto) is calculated from the monthly average data of climate station of Meteorology, Climatology and Geophysics (BMKG) Banjarbaru including the data of minimum temperature, maximum temperature, humidity, wind velocity, and sunshine during 2002-2012. With Cropwatt 8.0 program, it is obtained that Eto maximum of 5.32 mm/day occurred in September, Eto minimum of 3.86 mm/day occurred in June while Eto monthly average is 4.38 mm/day. In detail, Eto in irrigated areas of Riam Kanan are listed in Figure 2 and Figure 3.

Water Availability

Mainstay discharge in the watershed of irrigated area in Riam Kanan is calculated based on the calculation of simulations discharge of Riam Kanan River by using Mock method which obtains fortnightly discharge from 1990 to 2012 as is presented in Table 1, and Nreca method which obtains monthly discharge as in Table 2.

Irrigation Water Needs

Planting area and water needs for paddy as well as irrigation water needs MT1 of October 2011 until September 2012 are presented in Table 3.

Non Irrigation Water Needs

Domestic Water Needs

The standard domestic water needs in the study is 120 litres/person/day. The amount of domestic water needs is calculated based on the number of people in the area of study, which are the population in Banjar District, Banjarbaru City and Banjarmasin City which each served drinking water by 50%, 60% and 98% respectively. Domestic water needs in irrigated areas of Riam Kanan is 0.739 m³/sec (Table 4).

Non Domestic Water Needs

Non domestic water needs in irrigated area of Riam Kanan is 725,973x30 litres/day = 21,779,190 litres/day = 0.0252 m³/sec.

Industrial Water Needs

Industrial water needs in irrigated area of Riam Kanan is 0.1 x 0.739 m³/sec = 0.0739 m³/sec.

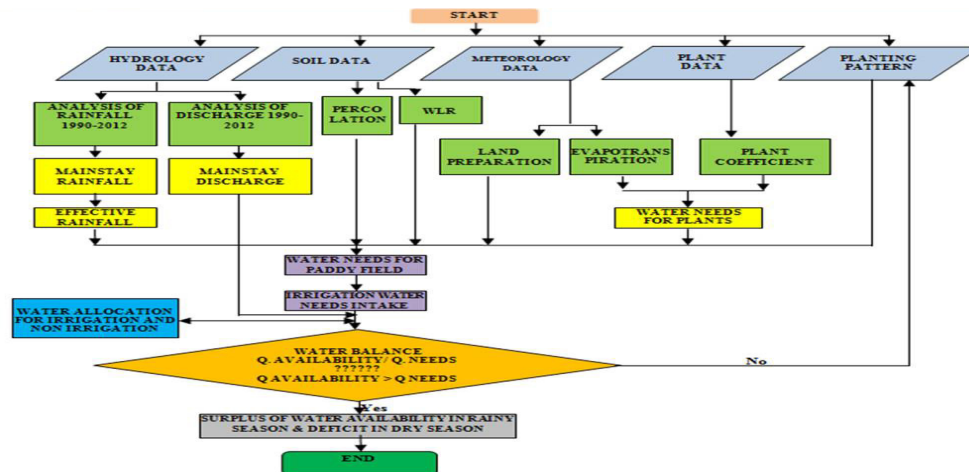
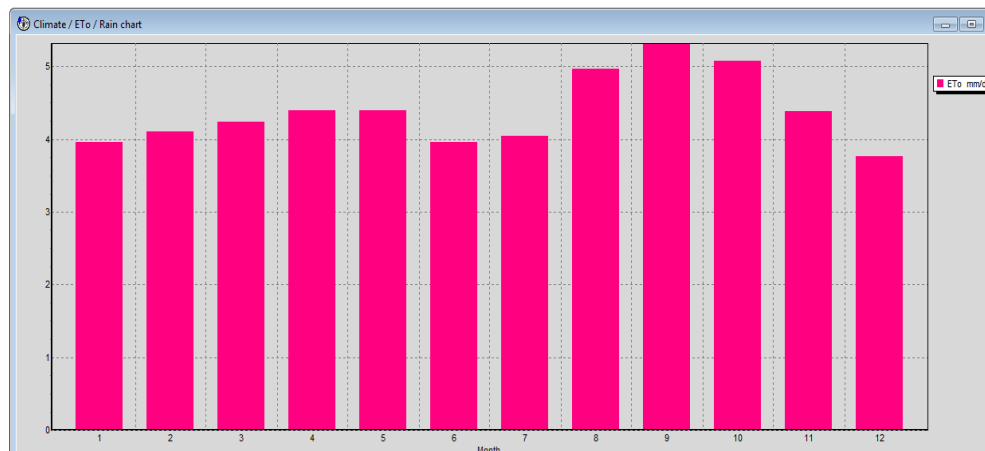


Figure 1. Flowcharge of Water Irrigation Management and Usage in Riam Kanan

Month	Min Temp °C	Max Temp °C	Humidity %	Wind km/day	Sun hours	Rad MJ/m ² /day	ETo mm/day
January	20.7	35.8	88	106	5.1	17.2	3.96
February	21.0	38.9	87	95	4.4	16.5	4.10
March	19.0	36.4	87	97	5.6	18.3	4.24
April	20.0	36.6	87	95	6.9	19.5	4.39
May	17.0	37.6	84	98	7.5	19.0	4.39
June	14.2	37.3	85	97	6.8	17.3	3.96
July	18.0	35.8	83	122	7.0	17.8	4.05
August	17.6	37.0	78	142	8.5	21.2	4.97
September	19.0	38.0	77	150	8.0	21.6	5.32
October	18.2	38.2	80	136	7.1	20.6	5.08
November	19.0	36.8	85	122	6.0	18.6	4.38
December	21.8	36.5	88	117	4.2	15.6	3.77
Average	18.8	37.1	84	115	6.4	18.6	4.38

Source: Calculation results

Figure 2. Monthly Average Evapotranspiration (Eto) of Irrigated Area in Riam Kanan year 2002-2012



Source: Calculation results

Figure 3. Monthly Average Evapotranspiration (Eto) Chart of Irrigated Area in Riam Kanan year 2002-2012

Table 1. Fortnightly Mainstay Discharge of Riam Kanan Watersheds Using Mock Method year 1990-2012

Months	Oct		Nov		Dec		Jan		Feb					
Week	I	II	I	II	I	II	I	II	I	II				
Mainstay Discharge 80% (M ³ /sec)	0.55	0.03	2.53	8.95	20.95	26.52	82.62	62.60	50.44	37.89				
March	Apr		May		Jun		Jul		Aug		Sep			
Week	I	II	I	II	I	II	I	II	I	II	I	II		
	37.14	35.61	34.32	18.63	15.15	7.36	3.74	1.99	1.48	0.68	0.36	0.17	0.19	0.009

Table 2. Monthly Average Mainstay Discharge of Riam Kanan Watersheds Using Nreca Method year 1990-2012

Months	Jan	Feb	March	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mainstay Discharge 80% (M ³ /sec)	9.357	10.87	8.617	8.86	8.311	9.649	8.673	6.997	6.951	7.22	9.286	9.75

Table 3. Irrigation Water Needs of Riam Kanan for Planting Period October 2011-September 2012

Months	Oct		Nov		Dec		Jan	
Week	I	II	I	II	I	II	I	II
Planted Area (Ha)	0	0	0	0	0	0	40	75
Water Needs (M ³ /sec)	0	0	0	0	0	0	0.019	0.054
Months	Feb		March		Apr		May	
Week	I	II	I	II	I	II	I	II
Planted Area (Ha)	325	470	582	810	1151	1712	2802	3666
Water Needs (M ³ /sec)	0.276	0.507	0.605	0.84	1.24	1.69	3.399	4.33
Months	Jun		Jul		Aug		Sep	
Week	I	II	I	II	I	II	I	II
Planted Area (Ha)	4181	4642	4642	4642	4642	4642	4642	4642
Water Needs (M ³ /sec)	6.355	7.39	7.584	8.60	8.596	9.023	9.02	0

Source: Calculation results

Table 4. Domestic Water Needs in Irrigated Area of Riam Kanan

No	District/City	Growth (%)	Population (head)		Number of being served (%)	Water Needs (litre/day)
			2010	2012		
1	Banjar	2.16	257,320	268,556	50	16,113,360
2	Banjarbaru	2.16	125,285	130,756	60	9,414,443
3	Banjarmasin	2.16	312,740	326,396	98	38,381,170
	Total	-	696,645	725,708	-	63,908,973 l/day (0.739M ³ /sec)

Source: Calculation results

Water Needs for Fishery

The number of fish ponds in irrigated area of Riam Kanan in 2012 covered 841.7 hectares. Water needs for fishery in irrigated area of Riam Kanan is 841.7 Ha x 7 mm/day = 0.068 M³/sec.

Water Needs for River Preservation

The number of population in irrigated area of Riam Kanan is 725,708 people and water needs in 2012 was determined by 360 litres/capita/day, so the water needs for river flushing of Riam Kanan = $725,708 \times 360$ litres/day = 261,254,880 l/day or 3,023.78 l/sec = 3.023 M³/sec.

Total Water Needs

The total water needs can be obtained by adding up the total water needs of various purposes of domestic water needs, non domestic water needs and industrial water needs, fisheries, and river flushing. Furthermore, the effect of water loss is also calculated to obtain the daily average of water needs by incorporating the influence factors of water needs. Water loss is estimated about 30% of the domestic water needs. Water needs in irrigated area of Riam Kanan is 13.77 m³/sec which occurred in August and a minimum of 4.48 m³/sec occurred in October as can be seen in Table 5.

WATER BALANCE

The analysis of water balance, water availability and water needs of fortnightly averages from 1990 to 2012 by using Mock methods can be seen in Table 5 and Figure 4, while Nreca method is in Table 6 and Figure 5.

Table 5. Water Balance of Fortnightly Average of Riam Kanan Watershed by Using Mock Method year 1990-2012

<i>Months</i>	<i>Oct</i>		<i>Nov</i>		<i>Dec</i>		<i>Jan</i>	
<i>Week</i>	<i>I</i>	<i>II</i>	<i>I</i>	<i>II</i>	<i>I</i>	<i>II</i>	<i>I</i>	<i>II</i>
Mainstay Discharge 80% (M ³ /sec)	0.55	0.03	2.53	8.95	20.95	26.52	82.6 2	62.60
Water Needs(M ³ /sec)	4.48	4.48	4.50	4.50	4.52	4.52	4.56	4.60
Water Balance (M ³ /sec)	-3.93	-4.45	-1.97	4.45	16.43	22.00	78.0 6	58.00
<i>Months</i>	<i>Feb</i>		<i>March</i>		<i>Apr</i>		<i>May</i>	
<i>Week</i>	<i>I</i>	<i>II</i>	<i>I</i>	<i>II</i>	<i>I</i>	<i>II</i>	<i>I</i>	<i>II</i>
Mainstay Discharge 80% (M ³ /sec)	50.44	37.89	37.14	35.61	34.32	18.63	15.1 5	7.36
Water Needs(M ³ /sec)	4.84	5.07	5.20	5.44	5.86	6.32	8.05	8.99
Water Balance (M ³ /sec)	49.60	32.82	31.94	30.17	28.46	12.31	7.10	-1.63
<i>Months</i>	<i>Jun</i>		<i>Jul</i>		<i>Aug</i>		<i>Sep</i>	
<i>Week</i>	<i>I</i>	<i>II</i>	<i>I</i>	<i>II</i>	<i>I</i>	<i>II</i>	<i>I</i>	<i>II</i>
Mainstay Discharge 80% (M ³ /sec)	3.74	1.99	1.48	0.68	0.36	0.17	3.74	1.99
Water Needs(M ³ /sec)	11.04	12.07	12.30	13.31	13.35	13.77	11.04	12.07
Water Balance (M ³ /sec)	-7.30	-10.1	-10.82	-12.83	-12.99	-13.6	-7.30	-10.1

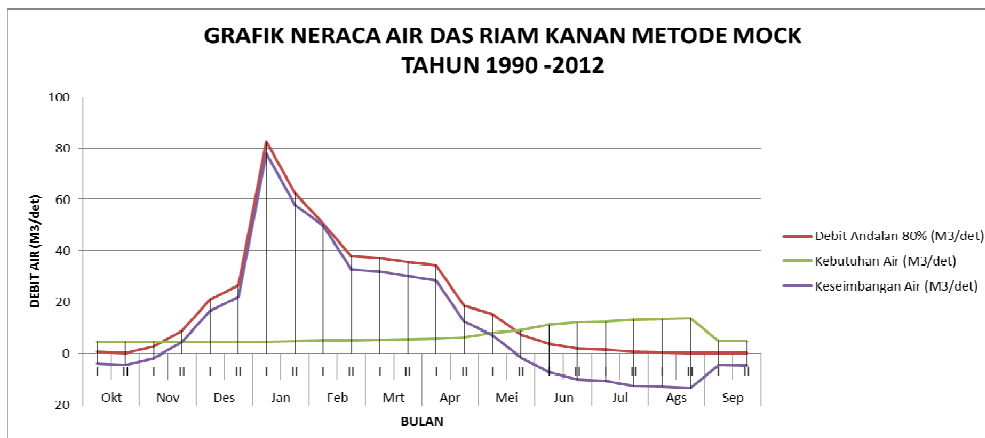


Figure 4. The Chart of Water Balance of Irrigated Watershed of Riam Kanan by Using Mock Method

Table 6. Water Balance of Monthly Average of Riam Kanan Watershed by Using Nreca Method year 1990-2012

Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Mainstay Discharge 80% (M ³ /sec)	7.22	9.29	9.75	9.36	10.87	8.62	8.86	8.31	9.65	8.67	7.00	6.95
Water Needs (M ³ /sec)	0.29	4.50	4.52	4.58	4.96	4.32	6.09	8.52	11.56	12.81	13.56	4.79
Water Balance (M ³ /sec)	6.93	4.79	5.23	4.78	5.91	4.30	2.77	-0.21	-1.91	-4.14	-6.56	2.16

Source: Calculation results

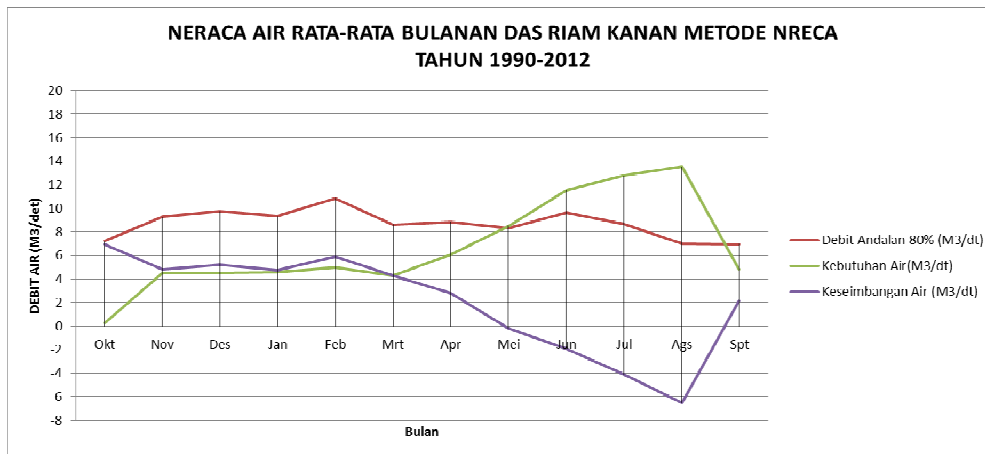


Figure 5. Water Balance of Monthly Averages of Riam Kanan Watershed by Using Nreca Method

From Table 5 and Table 6, it can be seen that:

1. Based on the calculation results by using Mock method in the rainy season from mid-November until mid-May, there was an excess of water. In the irrigated area of Riam Kanan, puddles occurred so that farmers cannot plant rice as a whole/simultaneously because of the topography condition. Water shortage was caused by inappropriate water management which does not suit the plants' needs in the field which are in May, June, July, August, September and October. The biggest water shortage occurred in June, July and August that was 10.1 to 13.6 m³/sec and the planted area was 4662 Ha (of 6000 Ha).

2. The calculation result based on Nreca method showed the same results as that of Mock, that is the surplus of water occurred in rainy season and water shortage in dry season. The third growing season is in May, June, July and August.

CONCLUSION

The results of the study show that:

1. Water usage is not managed efficiently; in rainy season, the water is not used for irrigation, while in dry season the water shortage for rice farming happened. The water shortage occurs when the crops (paddy) need water for its growth, which occurred from May 2012 to September 2012.
2. In rainy season, water is not used for agriculture because the paddy fields are covered by water and only few farmers would like to plant paddy that is from November 2011 to March 2012.
3. Water balance analysis in irrigation area of Riam Kanan by using Mock and Nreca methods, by the time the water is needed for irrigation, the water has deficit from May 2012 to September 2012 of 0.21 until 6.56 m³/sec.

SUGGESTIONS

To be able to efficiently utilize the irrigation water, the following is needed

- a. The existing irrigation systems need to be added with a small polder system. The distribution of water through the polder plots covers an area of 10 Ha and is regulated by farmer groups. With the addition of pumps, water can be managed by dumping water in rainy season and adding water in dry season.
- b. Non irrigation water usage needs to be re-arranged, such as for drinking water and aquaculture.
- c. Proper control of water is needed so that the period for paddy growth will not be interrupted. Plant growth with lack of water will cause paddy plants flower prematurely and it causes the lacking of hybrid and the production is also not qualified.
- d. A control towards the usage of irrigation water needs to be increased, so that water will be used in accordance with the plans and planting schedules. Thus, the fields which are usually planted once a year can be planted three times a year.
- b. Paddy fields should be maintained as perennial fields.

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REFERENCES

- [1] Amani, A. (2012). Modeling Water Supply and Demand for Effective Water management Allocation in the Jordan Valley. *Journal of Agricultural and Application* 1(1), 1-7.
- [2] Amir, M. (2009). Optimasi Potensi dan Pola Pemanfaatan Air Irigasi. *Jurnal Sumber Daya Irigasi Muhammadiyah Kendari*, Edisi Januari 2009 No 15.
- [3] Andales, A. A., Chavez, J. L. & Barder, T. A. (2011). *Irrigation Scheduling. The Water Balance Approach* Crop Series Irrigation. Colorado State University Fact Sheet No. 4.707.
- [4] Andarwayanti, Ussy, & Montarsih, L. (2011). Climate Change effect on Water balance at Pekalen Watershed Jawa Timur, Indonesia. *International Journal of Academic Research*, 3(2).
- [5] Arun, K. M. & Nethaji Mariapan, V.E. (2011). *Water Demand Analysis of Municiple Water Supply Using Expanet Software. International Journal on Applied Bio Engineering*, 5(1).
- [6] Asdak, C. (2010). *Hidrologi dan Pengelolaan Daerah Aliran Sungai*. Yogyakarta: Gadjah Mada University Press.
- [7] Bambang, T. (2010). *Hidrologi Terapan*. Beta Offset Yogyakarta: Edisi Kedua.
- [8] Bagus, B. M. (2005). Optimasi Kebutuhan Air Irigasi Dengan Menggunakan Solver (Optimization of Irrigation Water Requirement by using solver). *Jurnal F.T.Unram*, 1(1).
- [9] Bakhtiar. (2008). *Kajian Perbandingan Debit Andalan Sungai Cimanuk Metode Water Balance dan Data Lapangan*. Jurnal Ilmiah MKTS Badan Kejuruan Sipil, PII Vol 16 No 2.
- [10] Djarman K. & Irmak S. (2011). Actual Crop Evapotranspiration and Alfafa and Gross Reference Crop Coefisien of Maize underfull and Limited Irrigation and Rainfall Condition. University of Nebraska-Lincoln. *Journal of Irrigation and Drainage Engineering* 139(6).
- [11] Dudung Darusman, W. (2011). Nilai Ekonomi Domestik dan Air Irigasi Pertanian. *Jurnal Managemen Hutan Tropika*, 1(12).
- [12] Fakhurrrazi. (2011). *Analisis Keseimbangan Air Daerah Aliran Sungai Asam-Asam, Kab. Tanah Laut Kalimantan Selatan*. Thesis Unlam Banjarmasin.
- [13] Ge Sun, S.G. (2008). Infact of Multiple Stresses on Water Demand and Supply across the South Eastern United States. *Journal of the American Water Resources Association*, 44(6), 1441-1457.
- [14] Hadisusanto, N. (2011). *Aplikasi Hidrologi*. Malang: Penerbit Jogja Mediautama.
- [15] Helmi. (2011). Peranan Lembaga P3A / Kejruean Blang Dalam Kontek Ekonomi Daerah Tentang Pengelolaan Air Irigasi di Propinsi Aceh. *Jurnal Sains Riset*, 1(12).
- [16] Ijaz Hussain, Zakir Hussain, Max Boolh Sial; et.al. (2011). *Water, Balance, Survey, Demand and Irrigation Efficiency of Indus Basin. Pakistan Economic and Social Review*, 49(1), 13-38.
- [17] Lily, M. (2008). *Pengaruh perubahan cuaca terhadap optimasi irigasi dengan program linier* (Edisi 1). Citra Malang: Penerbit Percetakan CV.

- [18] Lily, M. L. (2011). Reliability Performance Tambak Pocok Small Dam Bangkalan of Indonesia. *Asian Journal of Natural and Applied Sciences*, 1(2).
- [19] Muhjidin, M. H. 2011). *Azas Irigasi dan Konservasi air* (Edisi 1). Yogyakarta: Percetakan Bursa Ilmu.
- [20] Richard, G., Allen, L. S., Pereira, D. R. et al., (2000). *Crop Evapotranspiration*, Utah State University Logan, Utah USA. FAO Irrigation and Drainage Paper No 56.
- [21] Roni, K. (2010). Peningkatan Kinerja Jaringan Irigasi Melalui Penerapan Manajemen yang Tepat dan Konsisten pada Daerah Irigasi Cimaraya. *Jurnal Teknik Sipil. Tasikmalaya*, 17(2).
- [22] Rudy Sulistyono dan Soemarno. (2009). *Efek Rumah Kaca, Pemanasan Global, Perubahan Iklim Global*. Unibraw, Malang: PPSUB.
- [23] Sarwono, H. H. & Luthfi, R. M. (2005). *Tanah Sawah, Karakteristik, Kondisi, dan Permasalahan Tanah Sawah di Indonesia*. Malang, Jawa Timur: Bayumedia Publishing.
- [24] Setyawan. (2009). Neraca Air di Pulau Bali. Forum GeogShih-Kai Chen and Chen Wuing Liu. 2001. Analysis of Water Movement in Paddy Rice Fields. *I Journal of Hydrology*, 260(2002) 2006.
- [25] Sonia, T. (2012). *Neraca Air Tanah, Tugas Terstruktur II Irigasi dan Drainase*. Unibraw, Malang: Fakultas Pertanian.
- [26] Sudaryoko, Y. (1986). *Kriteria Perencanaan Bagian Perencanaan Jaringan Irigasi KP – 01*. Departemen Pekerjaan Umum, Jakarta.
- [27] Sugeng, P. (2008). Evaluasi Kebutuhan Air Tanaman di 12 Kecamatan Wilayah Kabupaten Malang. *Fakultas Pertanian Unibraw Malang, Agritek*, 16(4), hal 734-742.
- [28] Yayuk, S. S. (2009). Analisis Kebutuhan Air Untuk Penyiapan Lahan dan Tanaman Pangan Dalam Perencanaan Jaringan Irigasi di Kawasan Kaibun, Kabupaten Kutai Timur. *Jurnal Agrifor*, VIII (1).
- [29] Zulkifli, D. (2012). Analisa Neraca Air Permukaan Daerah Aliran Sungai Renggung Untuk memenuhi Kebutuhan Air Irigasi dan Domestik Penduduk Kab, Lombok Tengah. *Jurnal Teknik Pengairan*, 3(2), hal 87-98.