IOP Conference Series: Materials Science and Engineering

PAPER • OPEN ACCESS

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To cite this article: S Azis 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **669** 012017

IOP Conf. Series: Materials Science and Engineering **669** (2019) 012017 doi:10.1088/1757-899X/669/1/012017

Shifting cropping shifts by efficient irrigation water to produce maximum rice productivity

S Azis[1]

[1] Civil Engineering Department, Nationale Institute of Technology Malang, East Java, Indonesia

cup.subandiyah@gmail.com

Abstract. Agriculture is the main support of the economy in Indonesia so that the sustainability of the productivity of paddy fields must be maintained properly. Rice fields rely heavily on irrigation water supplies from technical rigs. Continuity of water flow must be maintained in accordance with water requirements and cropping patterns in each paddy field. In connection with changes in conditions lately there has been a shift in the rainy season and the dry season which results in erratic discharge of surface water both in quantity and on time so that the use of irrigation water must be done wisely and efficiently to maintain the productivity of the yield of paddy fields. From the results of the implementation of the cropping pattern set by the relevant agency there has been a deviation of 13.81%, which means that it is necessary to improve the implementation of cropping patterns and adjust the time of rain so that rice productivity remains maximal.

1. Introduction

The provision of irrigation water for agriculture needs to be managed in a wise and sustainable manner so that its existence and functions are maintained, one of which is to provide benefits in agriculture. The Irrigation Area (DI) Molek is one of 44 Irrigation Areas in the Malang-Indonesia Regency area which has 3,983 hectares of paddy fields. Maintenance of irrigation network is also very important in order to ensure continuity of irrigation water allocation. [1]

Planting planning is outlined in the planting document called the Global Planting Plan (RTTG). From year to year, the method of preparing this Global Planting Plan has not changed even though the current situation and conditions are different.

The duration of the rainy and dry seasons is not fixed, sometimes the rainy season lasts less than 6 (six) months and sometimes more, as well as the dry season [2]. This condition causes the availability of surface water to become erratic and if the surface water is affected, the water discharge conditions are also affected so that it needs to be done by adjusting the surface water adaptation to climate change [3]. Climate change is projected to have a significant impact on conditions affecting agriculture [4].

From the results of the evaluation of the Global Planting Plan presented in Table 1 attached below, it can be concluded that there has been a deviation in the pattern of cropping arrangements of 13.81%, meaning that the implementation of the Global Planting Plan is not in accordance with the plan and needs to develop a new Global Planting Plan applicative and dynamic and keep up with the progress of the rain discharge conditions.

Table 1. Evaluation of the global planting plan

Irrigation / Raw Rice Field Area (Ha)	RTTG (Ha)	Realization of Planting Patterns Rice Special (Ha)	Compliance with RTTG (%)	Deviation (%)
DI Molek 3983	3974	3425	86.11	13.81

From the problems that occur, make the background and rationale for doing research to produce an appropriate analysis of water needs as a basis for determining the Global Planting Plan.

All stakeholders involved in the planning and implementation of the allocation of irrigation water understand climate change situations and conditions that are very influential on surface water and irrigation water so they argue that the Global Planting Plan arrangement must be adapted to climate change conditions to avoid the possibility of crop failure. [5].

More and more research shows that the world is warming and will continue to warm up when greenhouse gas concentrations increase in the future [6]. Productivity is influenced by a number of climate change variables including rainfall patterns, temperature increases, changes in sowing and harvesting, water availability and land suitability [7]. One of the most important impacts of climate change is the change in water available at the regional and local levels [8].

2. Materials and methode

Administratively, Molek Irrigation Area is located in Malang Regency. The average annual rainfall is 1,500 mm. Water sources Molek Irrigation Area originates from Mount Arjuno which flows through Brantas River which is channeled through the 12.44 Km Molek canal. The research framework is as in Table 2.

Table 2. Study framework

No	Stages of Calculation / Analysis	Data source	Calculation / analysis method	Results
1	Data Quality Test	Historical rainfall and discharge data	Rescaled Adjusted Partial Sums Method	Analysis requirements are accepted (still within consistent limits) if the values of Q / (n0.5) and R / (n0.5) count smaller than the values of Q / (n0.5) and R / (n0.5)
3	Mainstay Debit	Debit Data	Weibull Method Pr = m / (n+1) * 100 %	Debit of Wet Season , Normal Season, Dry Season
4	Mainstay Rainfall	Historical rainfall data	$R_{80} = \frac{n}{5}+1$ (reliability 80 %) $R_{50}= \frac{n}{2}+1$ (reliability 50 %)	Mainstay Rain Pattern
5	Effective Rainfall	Historical rainfall data	Frequency Analysis Formula	rice : R_e = (0,70 x R_{80})/day secondary crops : R_e= R_{50}/day
6	Evapotranspiration	Climatology Data	Modified Penman	Eto , mm/day
7	Water Needs for Soil Processing and Nursery	The duration of the tillage	Determined	Land preparation = 30 days Soil processing + Nursery = 250 mm/day

Table 2. Study framework (cont.)

No	Stages of Calculation / Analysis	Data source	Calculation / analysis method	Results
8	Percolation	Soil sample data and map of soil type distribution	Soil Test in the Laboratory to determine permeability numbers	Percolation Numbers
9	Water Requirements for Land Preparation	Potential Evapotranspiration of the Penmann Modification Method, Percolation Calculation	Suyono + Takeda C_{PL}= Cland preparation x Extensive planting ratio	IR, mm/day
10	Water Level Requirement	Estimated soil fertility	Determined	Change of Water Layer = 50 mm/month
11	Irrigation Efficiency	Debit Intake	Water loss in Primary, Secondary and Tertiary channels	Irrigation Efficiency Rainy Season Irrigation EfficiencyDry Season 1 Irrigation EfficiencyDry Season 2
12	Balance sheet needs and availability of water	Regional Irrigation of Irrigation Water Needs Molek	Water balance concept	Comparison of the value of the amount of availability to needs
13	Planting Pattern Simulation	Data and Simulation	Relative Crops Factor - Area of Relative Palawija	Irrigation Water Needs and Extensive Planting Area are optimal for Wet Season Year, Normal Season Year and Dry Season Year.
14	Preparation of a Global Planting Plan	Simulation Results	Rainy Season Early Planting Dry Season 1 Early Planting Dry Season 2 Early Planting	Wet Season Year Dry Season Year Normal Season Year

3. Results and discussion

The results of the analysis of the data and observations can produce the following result as shown in Table 3, Table 4, Table 5 and Table 6.

Table 3. Rainfall data consistency results

Station Name	Number		Coefficient Determination (%)
	Station	Stasiun Uji	
Sumber Pucung	36	Station 1	99.89
Kepanjen	39	Station 2	99.59
Kali Pare	40	Station 3	99.80
Pagak	64	Station 4	99.21

Table 4. Analysis of availability of irrigation intake discharge

Opportunity (80%)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
80	4.80	5.97	6.47	6.47	6.42	6.15	5.85	5.04	4.89	4.54	5.69	5.69
90	3.52	3.63	5.00	3.65	3.49	3.22	3.09	2.98	2.88	2.91	4.35	3.14
25	7.26	7.38	7.43	7.38	7.40	7.46	7.42	7.37	7.16	6.99	6.71	7.35

Table 5. Mainstay rainfall 80% and 50%

Month	Period	R 80 (mm)	R 50 (mm)	Month	Period	R 80 (mm)	R 50 (mm)
January	1	72.09	77.66	July	1	0.00	1.41
	2	29.32	55.80		2	0.00	0.00
	3	98.04	95.02		3	0.00	0.00
February	1	71.77	121.63	August	1	0.00	0.00
	2	122.96	61.68		2	0.00	0.00
	3	71.19	102.42		3	0.00	0.00
March	1	123.02	37.64	September	1	0.00	0.00
	2	87.31	84.56		2	0.00	0.06
	3	26.13	192.76		3	0.00	2.94
April	1	82.52	119.91	October	1	0.00	20.56
	2	63.62	99.42		2	0.00	41.37
	3	46.64	0.01		3	24.31	43.02
May	1	24.43	47.22	November	1	11.54	73.98
	2	32.68	31.43		2	41.77	58.50
	3	0.00	0.49		3	72.52	73.59
June	1	0.00	5.39	December	1	30.26	210.53
	2	0.00	14.12		2	43.95	15.88
	3	0.00	0.49		3	122.86	92.94

Table 6. Effective rainfall analysis

Month	Period	R 80 (mm)	Re rice			Re Secondary Plant		
			(mm)	(mm/day	(lt/sec/ha)	(mm)	(mm/day)	(lt/sec/ha)
January	1	72.09	50.47	5.05	0.59	77.66	7.77	0.90
	2	29.32	20.52	2.05	0.24	55.80	5.58	0.65
	3	98.04	68.63	6.86	0.80	95.02	9.50	1.10
February	1	71.77	50.24	5.02	0.58	121.63	12.16	1.41
	2	122.96	86.07	8.61	1.00	61.68	6.17	0.72
	3	71.19	49.83	4.98	0.58	102.42	10.24	1.19
March	1	123.02	86.11	8.61	1.00	37.64	3.76	0.44
	2	87.31	61.12	6.11	0.71	84.56	8.46	0.98
	3	26.13	18.29	1.83	0.21	192.76	19.28	2.24
April	1	82.52	57.77	5.78	0.67	119.91	11.99	1.39
	2	63.62	44.53	4.45	0.52	99.42	9.94	1.15
	3	46.64	32.65	3.26	0.38	0.01	0.00	0.00
May	1	24.43	17.10	1.71	0.20	47.22	4.72	0.55
	2	32.68	22.87	2.29	0.27	31.43	3.14	0.36
	3	0.00	0.00	0.00	0.00	0.49	0.05	0.01
June	1	0.00	0.00	0.00	0.00	5.39	0.54	0.06
	2	0.00	0.00	0.00	0.00	14.12	1.41	0.16
	3	0.00	0.00	0.00	0.00	0.49	0.05	0.01
July	1	0.00	0.00	0.00	0.00	1.41	0.14	0.02
	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 6. Effective rainfall analysis (cont.)

Month	Period	R 80 (mm)	Re rice			Re Secondary Plant		
			(mm)	(mm/day	(lt/sec/ha)	(mm)	(mm/day)	(lt/sec/ha)
August	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00
September	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00	0.06	0.01	0.00
	3	0.00	0.00	0.00	0.00	2.94	0.29	0.03
October	1	0.00	0.00	0.00	0.00	20.56	2.06	0.24
	2	0.00	0.00	0.00	0.00	41.37	4.14	0.48
	3	24.31	17.02	1.70	0.20	43.02	4.30	0.50
November	1	11.54	8.08	0.81	0.09	73.98	7.40	0.86
	2	41.77	29.24	2.92	0.34	58.50	5.85	0.68
	3	72.52	50.76	5.08	0.59	73.59	7.36	0.85
December	1	30.26	21.19	2.12	0.25	210.53	21.05	2.44
	2	43.95	30.76	3.08	0.36	15.88	1.59	0.18
	3	122.86	86.00	8.60	1.00	92.94	9.29	1.08
Total		1741.25	909.27	90.93	10.55	1782.42	178.24	20.68

Climatology data and Potential Evaporation for calculating irrigation water requirements is shown in Table 7.

Table 7. Climatology data and ETo (Potential Evaporation)

Month	Average Temperature °C	Humidity%	Wind velocity km/day	Duration of solar radiation hour	Radiation MJ/m²/day	ETo (Potential Evaporationl` mm/day
January	22.9	76	95	6.1	19.3	3.81
February	23.2	76	94	5.5	18.5	3.73
March	23.2	76	76	6.3	19.3	3.77
April	23.4	71	83	6.6	18.5	3.66
May	23.1	68	91	7.8	18.6	3.58
June	23.3	69	98	7.8	17.7	3.42
July	22.4	69	102	7.9	18.2	3.46
August	22.2	70	102	8.3	20.2	3.78
September	22.7	72	102	8.6	22.3	4.20
October	23.0	70	94	8.2	22.5	4.34
November	23.4	68	91	8.2	22.5	4.43
December	22.8	73	89	7.0	20.5	4.02

The duration of land preparation is 30 days. Water requirements for tillage and nursery are 250 mm which consists of 200 mm used for saturation and 50 mm for nursery. To estimate the water requirements for land preparation, the percolation value in the study area must be known. The percolation value is shown in Table 8.

Table 8. Magnitude of Percolation Value

No	Kinds of Land	Vertical percolation (mm/day)
1.	Sandy loam	3 – 6
2.	Loam	2 - 3
3.	Clay	1 – 2

Then the water requirements for land preparation can be calculated which the results whichare shown in Table 9.

Table 9. Water requirements for land preparation

Month	Eto mmday	Eo mm/day	P mm/day	M mm/day	S mm	T days	K	IR mm/day
January	3.810	4.191	4.5	8.691	250	30	1.0429	13.42
February	3.730	4.103	4.5	8.603	250	30	1.0324	13.36
March	3.770	4.147	4.5	8.647	250	30	1.0376	13.39
April	3.660	4.026	4.5	8.526	250	30	1.0231	13.31
May	3.580	3.938	4.5	8.438	250	30	1.0126	13.25
June	3.420	3.762	4.5	8.262	250	30	0.9914	13.14
July	3.460	3.806	4.5	8.306	250	30	0.9967	13.17
August	3.780	4.158	4.5	8.658	250	30	1.0390	13.40
September	4.200	4.620	4.5	9.120	250	30	1.0944	13.71
October	4.340	4.774	4.5	9.274	250	30	1.1129	13.81
November	4.430	4.873	4.5	9.373	250	30	1.1248	13.88
December	4.020	4.422	4.5	8.922	250	30	1.0706	13.58

Water Level Requirement is estimated at 50 mm. When using a 10 day period, the Water Level Requirement (WLR) of 50 mm is divided into 30 days, which is equal to 1.67 mm / day.

Irrigation efficiency is a comparison between the water discharge that arrives at the agricultural land and the water discharge coming out of the take-up gate. Before arriving at the paddy field, water must be flowed from the source through the main, secondary and tertiary canals Irrigation Efficiency.

Irrigation efficiency is calculated based on water loss during the drainage process along the channel. Irrigation efficiency can be shown in Table 10. Recapitulation of water balance conditions for existing planting can be shown in Table 11.

Table 10. Calculation of Irrigation Efficiency

Season	Month	Primary Loss (m3/sec)	Secondary Loss (m3/sec)	Irrigation Efficiency (%)	average (%)
Rainy Season	November	28.05	17.64	66.38	68.813
	December	20.30	16.65	71.26	
	January	20.82	21.33	68.22	
	February	19.36	20.74	69.39	
Dry Season 1	March	22.35	16.42	70.21	69.057
	April	22.42	16.64	70.03	
	May	21.83	19.06	68.94	
	June	25.28	19.05	67.05	
Dry Season 2	July	25.74	19.29	66.67	64.275
	August	28.80	18.91	65.29	
	September	30.17	19.64	64.21	
	October	33.35	23.08	60.93	

Table 11. Recapitulation of Water Balance Conditions for Existing Planting

Month	Period	Irrigation Needs Intake (m3/sect)	Dry Season River Discharge (m3sect)	Information	Normal Season River Discharge (m3/sec)	Information	Wet Season River Discharge (m3sec)	Information
January	1	7.06	3.52	Not enough	4.80	Not enough	7.26	Enough
	2	7.93	3.52	Not enough	4.80	Not enough	7.26	Not enough
	3	5.35	3.52	Not enough	4.80	Not enough	7.26	Enough
February	1	5.32	3.63	Not enough	5.97	Enough	7.38	Enough
	2	3.30	3.63	Enough	5.97	Enough	7.38	Enough
	3	4.91	3.63	Not enough	5.97	Enough	7.38	Enough
March	1	3.41	5.00	Enough	6.47	Enough	7.43	Enough
	2	4.39	5.00	Enough	6.47	Enough	7.43	Enough
	3	6.31	5.00	Not enough	6.47	Enough	7.43	Enough

Table 11. Recapitulation of Water Balance Conditions for Existing Planting (cont.)

Month	Period	Irrigation Needs Intake (m3/sect)	Dry Season River Discharge (m3sect)	Information	Normal Season River Discharge (m3/sec)	Information	Wet Season River Discharge (m3sec)	Information
April	1	4.54	3.65	Not enough	6.47	Enough	7.38	Enough
	2	5.32	3.65	Not enough	6.47	Enough	7.38	Enough
	3	6.32	3.65	Not enough	6.47	Enough	7.38	Enough
May	1	6.39	3.49	Not enough	6.42	Enough	7.40	Enough
	2	6.08	3.49	Not enough	6.42	Enough	7.40	Enough
	3	6.61	3.49	Not enough	6.42	Not enough	7.40	Enough
June	1	5.98	3.22	Not enough	6.99	Enough	7.46	Enough
	2	5.58	3.22	Not enough	6.99	Enough	7.46	Enough
	3	5.77	3.22	Not enough	6.99	Enough	7.46	Enough
July	1	6.65	3.09	Not enough	5.85	Not enough	7.42	Enough
	2	6.67	3.09	Not enough	5.85	Not enough	7.42	Enough
	3	6.67	3.09	Not enough	5.85	Not enough	7.42	Enough
August	1	6.60	2.98	Not enough	5.04	Not enough	7.37	Enough
	2	7.04	2.98	Not enough	5.04	Not enough	7.37	Enough
	3	7.86	2.98	Not enough	5.04	Not enough	7.37	Not enough
September	1	8.61	2.88	Not enough	4.89	Not enough	7.16	Not enough
	2	8.48	2.88	Not enough	4.89	Not enough	7.16	Not enough
	3	7.66	2.88	Not enough	4.89	Not enough	7.16	Not enough
October	1	6.85	2.91	Not enough	4.54	Not enough	6.99	Enough
	2	6.22	2.91	Not enough	4.54	Not enough	6.99	Enough
	3	5.64	2.91	Not enough	4.54	Not enough	6.99	Enough
November	1	4.68	4.35	Not enough	5.69	Enough	6.71	Enough
	2	4.16	4.35	Enough	5.69	Enough	6.71	Enough
	3	3.56	4.35	Enough	5.69	Enough	6.71	Enough
December	1	4.52	3.14	Not enough	5.69	Enough	7.35	Enough
	2	5.32	3.14	Not enough	5.69	Enough	7.35	Enough
	3	4.37	3.14	Not enough	5.69	Enough	7.35	Enough

Considering that the planting in one year is divided into 3 (three) seasons, namely the Rainy Season (MH), Dry Season 1 (MK1) and Dry Season 2 (MK2), and based on the effective rainfall pattern, the rainy month is November to April. Good months of start the planting is as the follows.

- Schedule for early planting of November period I
- Schedule for early planting of November period II
- Schedule for early planting of November period II
- Schedule for early planting of December period I
- Schedule for early planting of December period II
- Schedule for early planting of December period III
- Schedule for early planting of January period I
- Schedule for early planting of January period II
- Schedule for early planting of January period III
- Schedule for early planting of February period I
- Schedule for early planting of February period II
- Schedule for early planting of February period III

4. Conclusion

This shift in planting time was generated from simulations of rise planting area and secondary crops which produced the most optimal planting area.
Based on the research, shifting planting schedule that produces maximum production is as follows.

IOP Conf. Series: Materials Science and Engineering **669** (2019) 012017 doi:10.1088/1757-899X/669/1/012017

Table 12. Conclusion

Season	Global Planting Plan of Eksisting	New Global Planting Plan of Wet Season Year	New Global Planting Plan of Normal Season Year	New Global Planting Plan of Dry Season Year
Rainy Season				
Group I	10 December	1 December	20 February	20 February
Group II	15 December	10 December	1 March	1 March
Group III	20 December	20 December	10 March	10 March
Dry Season 1				
Group I	21 March	1 April	20 June	20 June
Group II	25 March	10 April	1 July	1 July
Group III	30 March	20 April	10 July	10 July
Dry Season 2				
Group I	20 August	1 August	20 October	20 October
Group II	25 August	10 August	1 November	1 November
Group III	30 August	20 August	10 November	10 November

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