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Cropping Calendar at Dry Field Due to Soil Moisture Balance (Case study at South of Bali)

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ABSTRACT

This paper intended to evaluate soil moisture dynamics and balance in root zone. The analysis used the software of Cropwat for Windows. Case study was south of Bali, in which there was recently at drought condition. Output of the software included potential evapotranspiration, cropping water requirement, and soil moisture balance. The result gave any information that could be used as consideration in deciding cropping calendar.
Keywords: crop water requirement, soil moisture balance, cropping calendar.

INTRODUCTION

The result of any studies carried out in the State Hydrological Institute were simplified to present on the estimation of long-term dynamics of water resources and water use for all administrative and planning regions as well as current and anticipated more variations in water resources in the future [1]. Estimates were constructed and developed for changes in water use, load on water resources, water demand, and water availability.

Droughts influenced the design, planning, and management of water supply infrastructures. Hydrologists ascertain drought duration, period, severity, probability and pattern of recurrence from reconstructed records [2]. Drought was defined as an extended period of low stream flow during which the natural water supply and demand was not sufficient due to normal water needs. An extended period was one that caused stress to human and environmental water uses, and it was meaningful only in the context of specific water supply [2].

Cropping management at dry field was generally constrained by water supply, because the water supply at this field was depended on rainfall and water holding capacity. The probability of increasing cropping production at rainy agriculture was forced at how to maximize the production per-unit water. There was positive correlation between cropping water requirement and the production [3] [4]. Upton [5] expressed that the relation between water supply and cropping production was so complex and it could vary in frequency and intensity.

MATERIALS AND METHOD

Location study was at the south of Bali, in the Badung Regent Pecatu village, Banjar Tengah, Subak Temu Dewi Bali. Evaluation of irrigation water requirement and soil moisture balance was oriented for dry field agriculture. Analysis used Model of Cropwat for Windows. Data of meteorology was recorded from Ngurah Rai station. Data of soil and cropping was taken from Cropwat of Windows, as in Table 1 below

Table 1 Soil data used in simulation

Parameter	Value
Texture	: tough
Total of available moisture (TAM)	: 180 mm/m
Maximum infiltration rate	: 40 mm/day
Maximum root depth	: 1 m
Initial available moisture	: 180 mm/m

Penman-Monteith Method

$$P_{tot} < 250 \text{ mm: } Pe = P_{tot} \times \frac{125 - 0.2\, P_{tot}}{125} \text{ ...... (1)}$$

$$P_{tot} > 125 \text{ mm: } Pe = 125 + 0.1 \times P_{tot} \text{ .. .. (2)}$$

Note:
Pe = effective rainfall (mm) and P_{tot} = total rainfall

Formula of Soil Moisture Balance

$$SMD_t = SMD_{t-1} + ETc - PE - IR + RO + DP \text{....(3)}$$

Note:
SMD_t and SMD_{t-1} = depletion of soil moisture (mm) at period of t and t – 1
ETc = actual evapotranspiration (mm)
PE = effective rainfall (mm)
IR = depth of irrigation (mm)
RO = runoff (mm)
DP = depth percolation (mm)

Formula of reduction of cropping yield

$$\left(1 - \frac{Ya}{Ym}\right) = ky \left(1 - \frac{ETa}{ETm}\right) \text{ ....(4)}$$

$$\left(1 - \frac{Ya}{Ym}\right)_i = 1 - \left(\frac{Ya}{Ym}\right)_1 * \left(\frac{Ya}{Ym}\right)_2 * \dots\dots * \left(\frac{Ya}{Ym}\right)_i \quad (5)$$

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Note:
i = phase of cropping growth
Ky = reduction factor of cropping yield
Ya, ETa = product and actual evapotranspiration
Ym, ETm = product and potential evapotranspiration

Average of effective rainfall (mm) and potential evapotranspiration (ETo, mm/day) was described as in Table 2

Table 2 Average effective rainfall (mm) and potential evapotranspiration (mm/day) on 2000-2009

Month	Average	
	ETo (mm/day)	Effective rainfall (mm)
Jan	4.40	162.2
Feb	4.68	154.5
Mar	4.92	150.9
Apr	5.25	122.9
May	5.40	58.3
June	5.34	30.5
July	5.32	15.8
Aug	5.56	13.8
Sep	5.38	22.0
Oct	5.18	65.6
Nov	4.65	87.1
Dec	4.19	154.6

Cropping was evaluated from cassava, corn, ground peanut, and sweet potato. Simulated cropping pattern was cassava – cassava, corn – corn, ground peanut – ground peanut, sweet potato – sweet potato, cassava – ground peanut, corn – ground peanut, ground peanut – corn, and sweet potato – ground peanut. Crop development requirements and indicators were described as in Table 3 below.

Table 3 Crop development requirements and indicators

Crop	Indicator	Phase of growth				Total
		I	II	III	IV	
Cassava	Phase duration (day)	20	40	90	60	210
	Kc	0.30	>>>	1.10	0.50	
	Ky	0.45	0.80	0.70	0.20	
	Depth of root (m)	0.30	>>>	0.40	0.40	
	Depletion (p)	0.20	>>>	0.20	0.20	
Corn	Phase duration (day)	21	34	38	10	103
	Kc	0.30	>>>	1.20	0.50	
	Ky	0.40	0.40	1.30	0.50	
	Depth of root (m)	0.30	>>>	0.60	0.60	
	Depletion (p)	0.50	>>>	0.50	0.80	
Sweet potato	Phase duration (day)	20	30	45	15	110
	Kc	0.30	>>>	1.15	0.65	
	Ky	0.45	0.80	0.80	0.30	
	Depth of root (m)	0.25	>>>	0.40	0.40	
	Depletion (p)	0.30	>>>	0.50	0.50	
Ground peanut	Phase duration (day)	15	25	30	25	95
	Kc	0.40	>>>	1.15	0.60	
	Ky	0.40	0.60	0.80	0.40	
	Depth of root (m)	0.10	>>>	0.30	0.30	
	Depletion (p)	0.45	>>>	0.45	0.50	

RESULTS AND DISCUSSION

Result of cropping water requirement due to Cropwat for Windows was seemed that was variation among the pattern as well as cropping type. Soil moisture balance and yield reduction was also seemed that all of the patterns and cropping time was not at the same condition. Soil moisture balance and yield reduction was described as in Table 4 below.

Table 4 Soil Moisture Balance and Yield Reduction on Wet Season (MH)

Pattern	Crop-1	Cropping time	Effective rainfall (mm)	ETc (mm)	ETc/ETm (%)	End-SMD (mm)	Yield reduction (%)
UK – UK	Cassava	22/10	822.6	844.7	98.3	22.1	1.9
		29/10	812.3	840.4	97.2	28.1	3.0
		05/11	788.2	828.0	95.2	39.8	5.3
		12/11	760.0	808.5	92.3	48.5	8.5
JG – JG	Corn	22/10	382.2	387.0	100	4.9	0.0
		29/10	374.9	386.0	100	11.1	0.0
		05/11	383.6	386.0	100	2.3	0.0
		12/11	378.8	386.9	100	8.1	0.0
KT – KT	Ground peanut	22/10	359.8	371.1	100	11.3	0.0
		29/10	366.0	368.7	100	2.7	0.0
		05/11	358.7	367.3	100	8.6	0.0
		12/11	351.8	366.8	100	14.9	0.0
UJ – UJ	Sweet potato	22/10	407.3	420.1	100	12.8	0.0
		29/10	416.4	419.4	100	3.0	0.0
		05/11	410.0	419.7	100	9.7	0.0
		12/11	403.8	420.8	100	17.1	0.0

Result showed that cropping time started at rainy season (MH) did not influence the difference between soil moisture balance and cropping yield. Therefore, it was no difference to start cropping at fourth week and after it on October or the first and second week on November due to soil moisture balance and cropping yield. But there was difference condition at dry season (MK-1). Soil moisture balance and yield reduction at dray season was described as in Table 5 below.

Table 5 Soil Moisture Balance and Yield Reduction on Dry Season 1 (MK-1)

Pattern	Cropping-2	Cropping time	Effective rainfall (mm)	ETc (mm)	ETc/ETm (%)	End SMD (mm)	Yield reduction (%)
JG – JG	Corn	09/02	323.2	411.5	93.5	88.3	8.1
		16/02	291.7	387.3	87.1	95.6	16.1
		23/02	266.2	361.9	80.7	95.7	24.2
		02/03	236.9	337.0	74.5	100.1	31.9
KT – KT	Ground peanut	01/02	386.2	406.7	99.8	20.5	0.2
		08/02	360.9	396.9	96.3	36.0	2.6
		15/02	333.2	376.4	90.3	43.2	6.8
		22/02	310.6	352.5	83.7	41.9	11.4
UJ – UJ	Sweet potato	16/02	310.8	371.8	77.0	61.0	25.3
		23/02	277.7	342.8	70.3	61.5	32.7
		02/03	247.1	314.7	64.0	67.6	39.6
		09/03	221.5	288.1	58.2	66.6	46.0
JG – KT	Ground peanut	09/02	355.5	394.1	95.4	38.7	3.2
		16/02	336.6	373.6	89.5	37.0	7.4
		23/02	305.5	348.6	82.7	43.6	12.1
		02/03	273.2	321.0	75.4	47.8	17.2
KT – JG	Corn	01/02	349.8	431.2	99.2	81.4	1.1
		08/02	329.0	414.3	94.3	85.3	7.2
		15/02	296.9	390.9	88.0	94.0	14.9
		22/02	266.1	365.2	81.5	99.1	23.1
UJ – KT	Ground peanut	16/02	336.6	373.6	89.5	37.0	7.4
		23/02	305.5	348.6	82.7	43.6	12.1
		02/03	273.2	321.0	75.4	47.8	17.2
		09/03	246.0	293.1	68.2	47.1	22.2

For example, if corn was cropped at second week of February, the yield reduction was only < 10% from the potential yield, but if it was cropped at third week of February, the reduction was 15-20%, and at fourth week of February, the reduction was 20-25%. If it was cropped until the first week of March, the reduction would be reach 30-35%. This condition was caused by the impact of deficit level of soil moisture in the root zone. Deficit level of soil moisture was shown by the ratio of ETc/ETm was more decreased. Little value of this ratio showed that available soil moisture was not enough to supply cropping water requirement.

Simulation results showed that high risk of yield reduction for second crop at dry season (MK-1) was ground peanut-ground peanut or corn-ground peanut. The first cropping calendar for second crops was described as in Table 6 below.

Table 6 the first cropping calendar for second crops

Cropping pattern	Oct				Nov				Dec				Jan				Feb				Mar				Apr				May				June				July			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Cassava-Cassava																																								
Corn-Corn																																								
G Peanut-G Peanut																																								
S Potato-S Potato																																								
Cassava-G Peanut																																								
Corn-G Peanut																																								
G Peanut-Corn																																								
S Potato-G Peanut																																								

CONCLUSION

Analysis of soil moisture balance due to Cropwat at South of Bali produced interesting results about the pattern of deficit soil moisture and the impact among cropping pattern. The evaluation showed there was the trend of soil moisture variability due to cropping schedule and the type of cropping pattern. Actual evapotranspiration was depended on the saving capacity of ground water and the capacity rainfall accepted by the ground.

Crop water requirement and soil moisture balance was very important. It was used as the consideration in model selection of cropping pattern so that would not reduce the potential production. The main constraint of dry field agriculture was restricted by available crop water requirement.

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