專 論

由月雨量推算水稻田間有效雨量

Estimation of Effective Rainfall for Paddy Field from Monthly Rainfall

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摘 要

印尼水稻需水量計算，蒸發散量多採用 Penman 氏修正式，各生長期需水量不同，以日雨量計算田間有效雨量至為繁複，且日雨量資料亦多散失不全。故筆者研究月有效雨量與月雨量之相關關係，以便由月雨量推算有效雨量，發現以双曲線方程式計算可獲幾近完全之相關，其回歸方程式如下：

$$\frac{1}{Re}=\frac{1}{R}+\frac{1}{aw}$$

式中 Ra 為月有效雨量，R 為月雨量，w 為月需水量，單位均為公厘。a 為常數，其值因雨量分佈情形而異，在中爪哇計算結果為 2，而在中及北蘇門答臘計算結果為1.4。本文介紹利用中爪哇資料之計算步驟，以供參考。

1. Introduction

Effective rainfall is the portion of rainfall that can be used for supplying or supplementing the water requirement of crops (evapotranspiration plus percolation). It is very important in planning of irrigation projects or in water management of irrigation systems to utilize the effective rainfall to a maximum extent so as to reduce irrigation requirement to decrease costs for water source development, to extend irrigation area, or to solve the problem of water shortage. Effective rainfall can be estimated from rainfall records. Various methods have been developed, among which the water budgeting method is the most reasonable but a time and labour consuming one. For the feasibility study of the three irrigation projects in Central Java, daily rainfall data at Gemolong station (No. 100b) from 1964 to 1977 were used to calculate the effective rainfall for paddy field by the water budgeting method. with the results obtained. a regression analysis was made to find out the relationship between monthly rainfall and monthly effective rainfall. The relationship fits a hyperbolic curve well and is presented in this report for reference of similar projects

2. Calculation of Effective Rainfall by Water Budgeting Method

Basic assumptions for calculation of effective rainfall for paddy field by water budgeting method are as follows:

a. The storage capacity of paddy fields for rainfall water is assumed to be 50mm in depth on average. In other words, the portion of daily rainfall exceeding 50 mm is considered to be ineffective.

b. For consecutive rainy days, or in case water stored in the field from previous rainfall is not yet entirely consumed, the effective rainfall is the portion of rain fall that replenishes the consumption of water requirement or refills the field to full capacity.

c. For the sake of a conservative estimate, effective rainfall is assumed to be received at the end of the day, and water requirement is consumed in the beginning of the day.

d. The rainfall water stored in the field at the end of a month is carried over to the next month and considered as effective rainfall of the next month and deducted from the current month.

The daily rainfall data from 1964 to 1977 at Gemolong Station (No. 100b) in the Kedung Kancil irrigation area, Central Java were used for the study. The computation was made on a daily basis and summed up each month. Table 3-1 shows the estimated monthly effective rainfall, Re6, Re8 and Re10 for water requirements of 6, 8 and 10 mm/day respectively.

3. Relationship Between Monthly Rainfall and Effective Rainfall

A regression analysis was made to find out the relationship between monthly rainfall and effective rainfall. Fitting a parabolic curve was firstly tried but the correlation coefficient was only 0.54. A perfect correlation was later obtained by fitting a hyperbolic curve. The computation is shown in Table 3-2 and the regression equations are as follows:

$$\frac{1}{Re6} = \frac{0.984}{R} + 0.096, \qquad r6 = 0.993$$

$$\frac{1}{Re8} = \frac{0.990}{R} + 0.062, \qquad r8 = 0.997$$

$$\frac{1}{Re10} = \frac{0.992}{R} + 0.047, \qquad r10 = 0.998$$

Where R is monthly rainfall in mm/day, Re6, Re8 and Re10 are effective rainfall in mm/day for water requirements of 6,8 and 10 mm/day, r6, r8 and r10 are the Correlation Coefficients.

Some special cases for the effective rainfall computed in Table 3-1, e. g., effective rainfall which is larger than the monthly rainfall due to carrying over of rainfall water from previous month, as we llas months with zero rainfall, are excluded in the regression analysis.

The above-mentioned regression equations can be simplified without causing significant error as follows:

$$\frac{1}{Re} = \frac{1}{R} + \frac{1}{2W} \qquad \text{for } R<2\,W$$

$$Re = W \qquad \text{for } R \geqq 2\,W$$

Where W is water requirement in mm/day.

Table 3-1: Monthly Effective Rainfall at Gemolong Station (100b)

Unit: mm/day

	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
January														
R	—	11.9	13.2	16.1	9.4	11.2	5.6	14.5	13.5	12.5	6.0	9.8	7.5	—
Re6	—	6.0	6.0	6.0	6.0	5.2	5.6	6.0	6.0	6.0	4.1	5.2	5.2	—
Re8	—	7.1	7.5	7.9	7.4	5.5	5.8	8.0	7.4	7.3	4.4	6.7	6.3	—
Re10	—	7.7	8.6	9.3	8.3	5.9	5.8	9.8	8.6	8.2	4.9	7.6	7.0	—
February														
R	7.8	11.1	14.1	18.6	21.7	12.8	10.4	13.4	6.2	22.8	9.5	7.4	4.9	15.5
Re6	4.3	6.0	5.9	6.0	6.0	5.8	6.0	6.0	5.7	6.0	5.3	6.0	3.9	3.4
Re8	4.6	7.3	7.2	7.9	8.0	6.3	6.9	7.1	6.0	8.0	6.5	7.0	4.2	4.6
Re10	5.0	9.0	8.5	9.3	10.0	7.3	7.4	7.9	6.2	10.0	7.1	6.6	4.8	5.7
March														
R	9.8	12.0	9.5	7.1	17.3	9.9	14.2	15.8	11.5	10.1	4.7	11.4	9.6	14.6
Re6	5.6	6.0	6.0	5.2	6.0	5.8	5.7	5.5	4.9	6.0	4.4	5.8	6.0	6.0
Re8	6.5	7.5	7.3	6.1	8.0	7.4	7.0	5.8	5.9	7.3	4.6	7.0	7.2	8.0
Re10	7.7	8.3	8.1	7.0	9.3	8.7	8.3	6.4	7.0	8.5	4.7	7.7	7.4	10.0
April														
R	10.7	5.5	8.0	3.9	11.7	11.4	8.6	4.7	4.8	7.0	6.9	6.7	1.0	12.7
Re6	5.5	4.4	3.6	4.5	5.1	6.0	5.8	4.7	5.3	4.9	4.5	5.1	2.5	4.9
Re8	6.6	5.3	4.0	4.9	6.1	8.0	6.9	5.0	5.9	5.2	5.2	5.6	2.4	5.5
Re10	7.8	5.4	4.5	5.3	7.1	9.0	7.3	5.3	5.7	5.4	5.7	5.8	2.2	6.0
May														
R	3.8	4.9	2.5	1.2	10.5	2.4	9.0	5.7	3.3	11.4	3.3	8.5	0	9.9
Re6	3.5	3.9	3.6	1.6	6.0	2.1	6.0	3.6	3.4	6.0	4.1	5.0	0	5.1
Re8	3.8	3.8	3.5	1.5	8.0	2.1	6.6	3.9	3.3	7.8	4.7	6.6	0	6.1
Re10	3.8	3.8	4.0	1.5	9.9	2.3	7.6	4.1	3.3	9.3	4.9	7.6	0	6.6
June														
R	1.1	5.7	4.4	0	7.0	1.9	1.4	3.2	0	2.2	0.7	0.7	0.6	5.9
Re6	1.3	3.0	3.6	0	3.8	2.9	2.1	3.5	0	3.2	0.7	1.1	0.6	4.1
Re8	1.1	2.7	4.2	0	5.4	2.9	2.3	3.4	0	2.8	0.7	0.4	0.6	4.5
Re10	1.1	2.8	4.8	0	5.2	2.7	1.8	3.4	0	2.2	0.7	0	0.6	4.5

Table 3-1: (Continued)

	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
July														
R	—	2.3	0	0	5.3	0.3	0.6	0.8	0	1.9	2.3	—	0	0
Re6	—	3.6	0	0	4.4	0.8	0.6	0.8	0	1.9	1.8	—	0	0
Re8	—	3.7	0	0	4.6	0.8	0.6	0.8	0	1.9	2.2	—	0	0
Re10	—	3.8	0	0	4.7	0.8	0.6	0.8	0	1.9	2.3	—	0	0
August														
R	1.9	0	0	0	2.7	0.1	0	0.2	—	2.7	3.8	0	2.3	0
Re6	1.8	0	0	0	3.2	0.1	0	0.2	—	2.4	3.9	0	0.6	0
Re8	1.8	0	0	0	3.2	0.1	0	0.2	—	2.4	3.8	0	0.8	0
Re10	1.8	0	0	0	3.2	0.1	0	0.2	—	2.4	3.8	0	1.0	0
September														
R	2.4	—	1.1	0	1.3	0.5	6.6	1.0	0	13.5	2.9	8.0	1.8	0
Re6	2.5	—	1.1	0	1.3	0.5	2.6	1.0	0	3.4	3.3	3.2	1.9	0
Re8	2.5	—	1.1	0	1.3	0.5	2.8	1.0	0	4.2	2.9	3.4	1.9	0
Re10	2.5	—	1.1	0	1.3	0.5	3.0	1.0	0	5.1	2.9	3.6	2.0	0
October														
R	11.2	—	8.1	2.9	4.9	9.7	6.1	8.5	5.0	5.0	8.7	7.5	7.2	0.5
Re6	4.4	—	4.9	1.6	3.9	4.1	4.2	2.9	2.1	4.5	4.1	4.0	5.2	0.5
Re8	5.4	—	5.6	1.8	4.5	5.0	4.8	3.6	2.5	4.8	5.0	4.7	5.8	0.5
Re10	6.0	—	6.1	2.0	4.6	5.8	5.2	3.9	2.5	5.2	5.8	5.3	5.7	0.5
November														
R	4.7	8.4	9.7	6.9	12.0	7.4	4.4	8.6	8.8	9.1	5.0	2.0	4.1	7.5
Re6	4.8	5.1	6.0	6.0	5.8	6.0	5.0	5.5	4.5	4.9	5.2	3.5	4.8	3.9
Re8	5.3	7.1	6.8	7.1	6.9	7.2	4.7	5.6	5.0	5.9	5.5	3.4	5.0	4.5
Re10	5.3	7.4	7.7	7.1	7.9	7.4	4.4	5.7	5.2	6.2	4.9	3.4	4.6	4.8
December														
R	9.9	10.5	7.4	11.0	6.2	12.4	11.1	10.5	11.4	—	6.5	15.9	5.1	—
Re6	5.4	6.0	6.0	6.0	6.0	5.5	4.5	6.0	6.0	—	5.7	5.0	3.3	—
Re8	7.0	7.5	6.8	6.7	6.7	6.2	5.2	6.7	8.0	—	5.8	5.5	3.6	—
Re10	7.8	8.2	7.1	7.4	6.5	6.7	5.7	7.6	8.6	—	5.9	5.9	3.7	—

Table 3-2: Regression Analysis

Item	J	F	M	A	M	J	J	A	S	O	N	D	Total	Mean
$\frac{1}{R}$	1.043	1.352	1.383	1.206	1.875	3.583	4.066	16.331	5.029	3.933	1.127	1.473	42.401	0.372
$\frac{1}{R^2}$	0.109	0.159	0.157	0.156	0.460	4.899	4.842	125.603	6.462	4.365	0.152	0.143	147.517	1.294
$\frac{1}{Re6}$	1.988	2.656	2.504	2.048	2.486	3.936	4.226	17.639	5.670	5.524	1.775	2.101	52.643	0.462
$\frac{1}{Re^2 6}$	0.365	0.526	0.452	0.429	0.700	5.058	4.978	128.260	6.750	5.220	0.357	0.418	153.963	1.350
$\frac{1}{Re8}$	1.650	2.233	2.094	1.769	2.282	3.873	4.115	17.222	5.568	4.836	1.531	1.832	49.005	0.430
$\frac{1}{Re^2 8}$	0.257	0.374	0.321	0.323	0.628	5.039	4.871	127.045	6.689	4.903	0.267	0.323	151.040	1.325
$\frac{1}{Re10}$	1.462	1.972	1.854	1.624	2.131	3.867	4.091	16.972	5.486	4.798	1.453	1.708	47.418	0.416
$\frac{1}{Re^2 10}$	0.203	0.294	0.293	0.274	0.558	5.033	4.852	126.482	6.534	4.777	0.242	0.284	149.826	1.314
$\frac{1}{RRe6}$	0.195	0.265	0.254	0.251	0.556	4.956	4.902	126.171	6.537	4.646	0.225	0.236	149.194	1.309
$\frac{1}{RRe8}$	0.164	0.230	0.220	0.218	0.533	4.948	4.856	125.990	6.527	4.560	0.195	0.209	148.650	1.304
$\frac{1}{RRe10}$	0.146	0.207	0.194	0.202	0.503	4.946	4.846	125.881	6.518	4.519	0.186	0.196	148.344	1.301
n	11	14	14	10	10	5	5	5	7	13	9	11	114	

$b_1=[\Sigma X-\Sigma X \Sigma y/n]/[\Sigma x^2-(\Sigma x)^2/n]$

Re6 : $[149.194-\frac{42.401\times 52.643}{114}]/[147.517-\frac{42.401^2}{114}]=129.614/131.746=0.984$

Re8 : $[148.650-\frac{42.401\times 49.005}{114}]/131.746=130.423/131.746=0.990$

Re10 : $[148.344-\frac{42.401\times 47.418}{114}]/131.746=130.707/131.746=0.992$

$b_0=\bar{Y}-b_1\bar{X}$

Re6 : $0.462-0.984\times 0.372=0.096$

Re8 : $0.430-0.990\times 0.372=0.062$

Re10 : $0.416-0.992\times 0.372=0.047$

Regression Eqn. : $\frac{1}{Re6}=\frac{0.984}{R}+0.096$

$\frac{1}{Re8}=\frac{0.990}{R}+0.062$

$\frac{1}{Re10}=\frac{0.992}{R}+0.047$

$r_6^2=\frac{10.984\times 129.614}{153.963-52.643^2/114}=0.9857$ $r_6=0.993$

$r_8^2=\frac{0.990\times 130.423}{151.040-49.005^2/114}=0.9934$ $r_8=0.997$

$r_{10}^2=\frac{0.992\times 130.707}{149.826-47.418^2/114}=0.9966$ $r_{10}=0.998$

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陸故會員允煦，閩屏南縣人，國立厦門大學土木系畢業，先後任臺灣省水利局工程師、規劃隊長、副總隊長及主任工程司，從事防洪灌溉與水利工程規劃，對河川治理及臺北地區防洪計劃貢獻尤多。民國六十三年自水利局退休，即爲中興工程顧問社延攬，擔任越南、菲、印尼等計劃服務，擘畫週詳，雖資料欠缺，輔佐稀少，仍克奮力以赴，爲業主與同僚所共欽。本年七月廿一日突因病仙逝，遽歸道山，實爲水利工程界之巨大損失，爰刊載其爲印尼某一計劃所作水文分析文，用誌哀思！