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Probable Evapotranspiration of Paddy Rice using Dry Day Index

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Abstract□To support some knowledge in planning irrigation system, short or long-term irrigation scheduling or determining irrigation reservoir capacity, it is necessary to estimate peak irrigation requirements and seasonal distribution of water demands for various return periods.

In this paper Dry Day Index and Probable Evapotranspiration were evaluated to decide seasonal consumptive use of paddy rice for a design year using several decades' daily rainfall data and 5 years'('82~'86) actual evapotranspiration data, respectively. To obtain Dry Day Index that is defined as the number of probable dry days for a given period, Slade unsymmetrical distribution function was adopted. Dry Day Index was analysed for 5 and 10-day intervals. Each of them was evaluated with return periods of 1, 3, 5, 10 and 20 year. Their singnificance was tested by χ^2 method. Based on these values, the Probable Evaportanspiration, that is the average daily ET both in dry days and rainy days during a given period, was estimated. Crop coefficient was also determined by the modified Penman equation proposed by Doorenbos & Pruitt.

Keywords□Dry day index, probable dry days, probable evapotranspiration, penman crop coefficient

I. Introduction

Irrigation can be defined as an artificial supply of water in the field to improve crop productivity and crop quality. The identification of proper irrigation time and necessary irrigation water requirements is very important to efficient use of irrigation water.

The consumptive use of paddy rice is determined by evapotranspiration and deep percolation during the growing period. Evapotranspiration(ET) depends on the meteorological factors such as temperature, humidity, wind speed, sunshine hour and solar radiation. Generally, ET shows large values in dry days and small values in rainy days. So, the presence of rainfall affects the amount of ET distinctly.

The estimation of ET on a probability basis will provide useful data in determining irrigation reservoir capaity and irrigation scheduling. Measurements of consumptive use of paddy rice been conducted during 5 years('82~'86) at 9 stations of

South Korea The actual ET can be taken as a representative value if it is measured under the same drought condition as the planning year, which is not the case in general. So, it is necessary to evaluate a representative ET according to short or long return periods.

This paper issues the evaluation of Dry Day Index(DDI) using several decades' rainfall data, and probable ET using both the DDI and 5 years actual ET in South Korea. In addition, the crop coefficient was estimated by the modified Penman equation(Doorenbos and Pruitt, 1977).

II. Dry Day Index

Dry Day Index is defined as the number of Probable Dry Days for a given period. If we plot daily rainfall data with amount on the abscissa and frequency on the ordinate, the distribution is inclined to the left extremely. To generate this distribution properly, Slade's partly unsymmetrical distribution function was adopted.

$$P(x)=\frac{1}{\sqrt{\pi}}\int_{-\infty}^{c\log\frac{d(x+b)}{t^2+1}} e^{-u^2}du \qquad (1)$$

where, $P(x)$: number of probable rainy days
x : average value of a class
b,c,d,t : parameters derived from the first, second and third moments

The calculating procedure of $P(x)$ is as follows ;

a) to obtain the upper limit of integral, the followings are computed by the class of rainfall event.

① $$\overline{X}=\frac{\Sigma fx}{\Sigma f},\ U_2=\frac{\Sigma fx^2}{\Sigma f}-\overline{X}^2,$$

$$U_3=\frac{\Sigma fx^3}{\Sigma f}-3\overline{X}\frac{\Sigma fx^2}{\Sigma f}+2\overline{X}^3$$

where, $\overline{X}$: average, U_2, U_3 : the second and third moments of arithmetic average, and f : frequency of a class

② t is obtained from the equation $t^3+3t-D=0$, where

$$t=|A|^{1/3}+|B|^{1/3},\ A=\frac{D}{2}+\sqrt{(\frac{D}{2})^2+1},$$

$$B=\frac{D}{2}-\sqrt{(\frac{D}{2})^2+1},\ D=\frac{U_3}{U_2^{1.5}}$$

③ $$b=\frac{(U_2)^{1/2}}{t},\ z=2.30258\cdot\sqrt{2}\cdot c=\frac{2.30258}{\ln(t^2+1)},$$

$$d=\frac{t(t^2+1)^{1.5}}{(U_2)^{1/2}},\ k=\frac{(t^2+1)^{1/2}}{b}$$

b) using the above values, rainfall amount(X) and the number of probable rainy days can be obtained by the following parameters.

$X=x-\overline{X}+b$, $s=\log kX$, $y=z\cdot s$, $f(y)$=the value of normal distribution

Finally, Probable Dry Days for 5 and 10-day intervals are obtained for each rainfall using the probable rainy day.

III. Probable ET and Crop Coefficients

Probable ET is defined by the average daily ET both in dry and rainy days during a given period. It can be expressed by the following equation.

$$PRET=((PDD\times ADET)+(PRD\times ARET))/N \qquad (2)$$

where, PRET : probable ET(mm/day)
PDD : probable dry days
PRD : probable rainy days
ADET : average ET in dry days (mm/day)
ARET : average ET in rainy days (mm/day)
N : days in a period

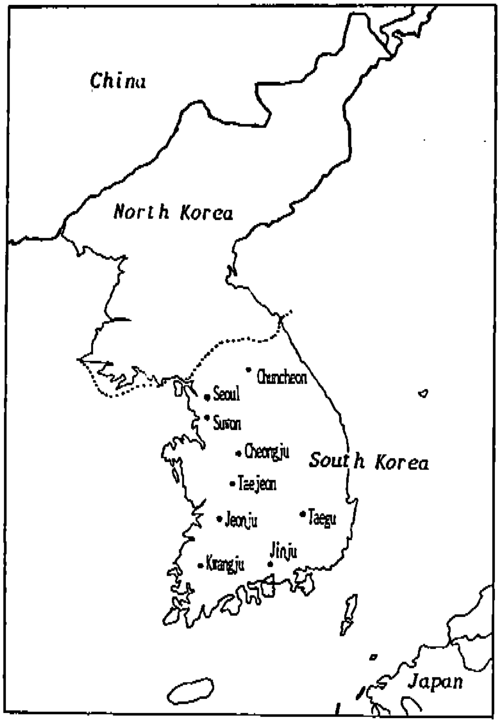


Fig. 1. Location of 9 stations in South Korea

Crop coefficient is evaluated from the relationship between the actual ET and potential ET. In this study, the modified Penman equation(Doorenbos and Pruitt, 1977) was used to calculate potential ET.

Ⅳ. Results and Discussion

1. Dry Day Index

Probable Dry Days(PDD) for 5 and 10-day intervals were evaluated at 9 stations of South Korea. The 9 stations might be largely categorized by 3 parts(northern, middle, southern) with the characteristics of similar rainfall pattern as shown in Fig. 1. Chuncheon belongs to northern part. Seoul, Suwon, Cheongju and Taejeon belong to middle part. Taegu, Jinju, Jeonju and Kwangju belong to southern part.

The PDDs were illustrated in Fig. 2. The number of PDD for 3 parts showed a little differences for each return periods. During the growing period of paddy(102 days) in case of 10 day intervals, the DDI for 1-yr return period were 55, 54, 59 days for northen, middle, southern part, respectively. For 3-yr return period it was 84, 85, 85 days and for 5-yr return period it was 84, 85, 86 days, respectively. For above 10-yr return period it was 102, 102, 102 days, respectively.

2. Probable ET

Probable ET was also estimated using the PDDs and actual ET. Actual ET was measured using lysimeters(Fig. 3) at 9 stations during 5 years (1982~1986). The probable Et were illustrated in Fig. 4. The probable ET increased in the order of northern, middle, and southern part. This shows that the meteorological factors such as temperature, sunshine hour and solar radiation are getting higher as moves down to the south even though the PDD showed little differcene among 3 parts. The maximum Probable ET occurred at early period of August for all 3 parts. For 10-day intervals, the probable ETs for 1-yr return period were 433. 7, 493.7, 504.2mm for northern, middle, southern part, respectively. Those for 3-yr retrun period were 538.0, 643.7, 650.1mm and for 5-yr retrun period were 538.9, 653.2, 657.1mm, respectively. Those for above 10-yr return period were 593.9, 724.9, 735.7mm, respectively.

3. Crop Coefficient

Crop coefficient was evaluated from the relationship between probable ET and Penman probable ET. Penman probable ET was calculated with the same procedure of probable ET using the modified Penman formula. The results were illustrated in Fig. 5. The crop coefficient for return periods inc-

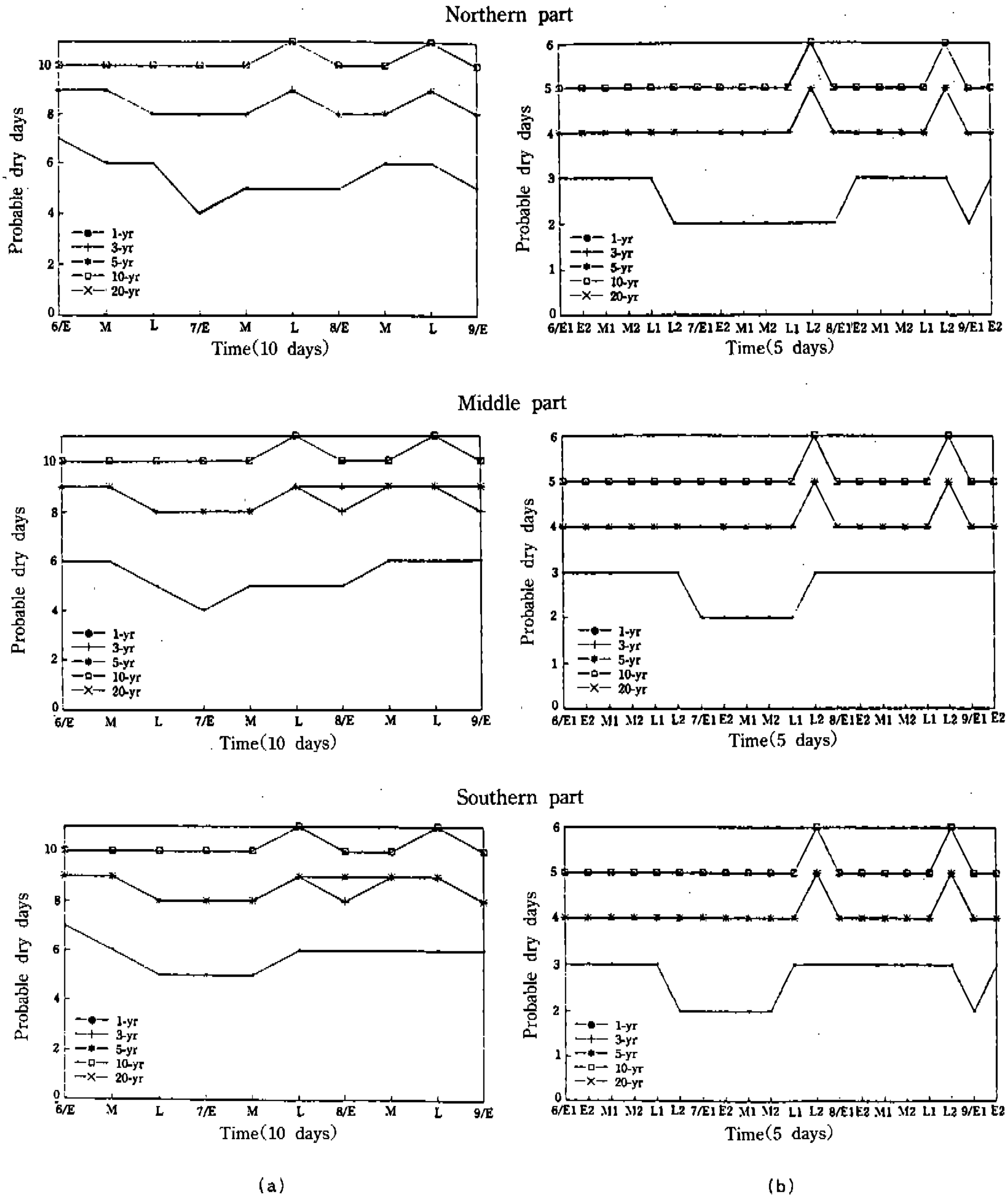


Fig. 2. Probable Dry Days with (a) 10 day and (b) 5 day intervals

reased in the order of northern, middle, and southern part. This shows that the Penman probable ET is less sensitive than the propable ET. The maximum crop coefficient was also occurred at the early period of August for all 3 parts of South Korea. All the crop coefficients were higher than 1.0. This means that the actual ET of paddy rice is larger than Penman ET.

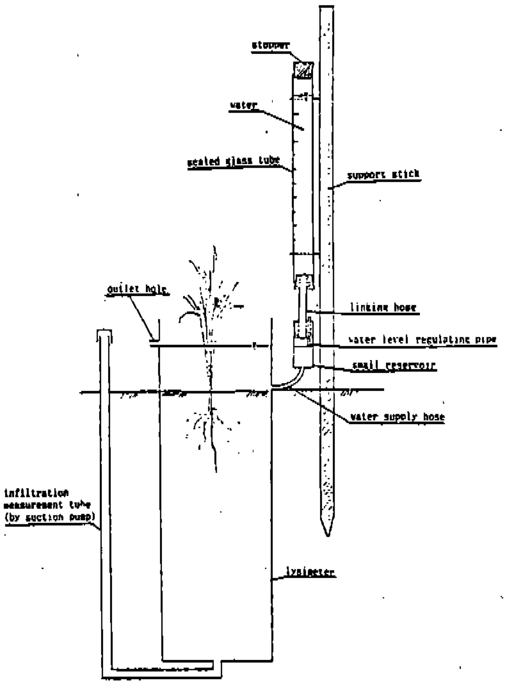
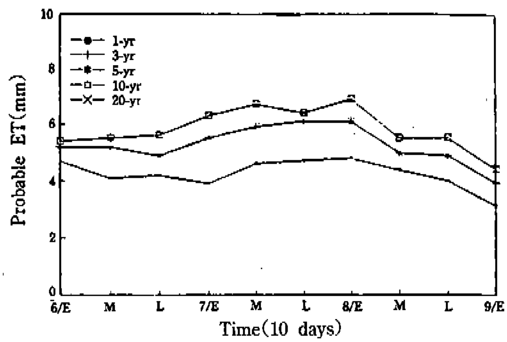


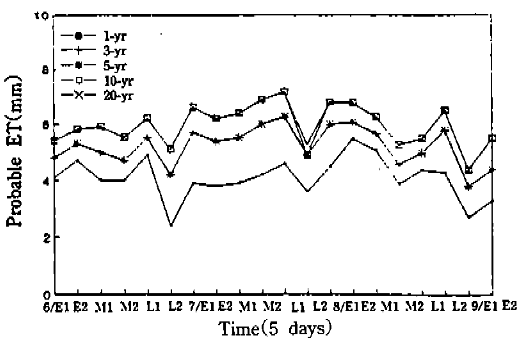
Fig. 3. Lysimeter structure for actual ET

V. Conclusions

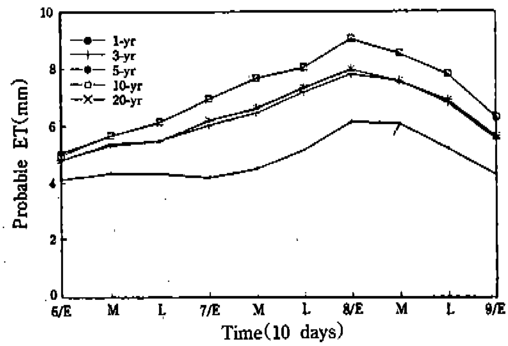
Dry Day Index, Probable ET and related Penman Crop coefficient during the growing period of paddy rice were evaluated for 3 parts(northern, middle, southern) in South Korea. These were evaluated for various retrun periods with 5 and 10 day intervals. These estimates may be useful for determining seasonal consumptive use of paddy rice at a design year, for providing the peak irrigation requirements, and for planning irrigation systems.

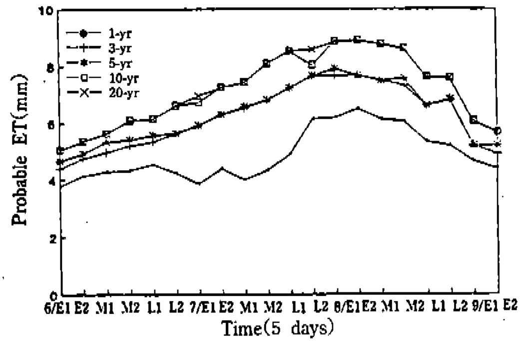
Northern part



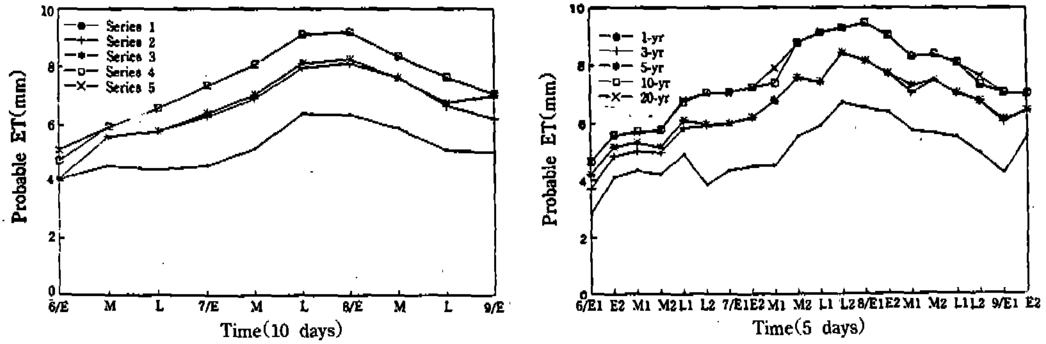


Middle part





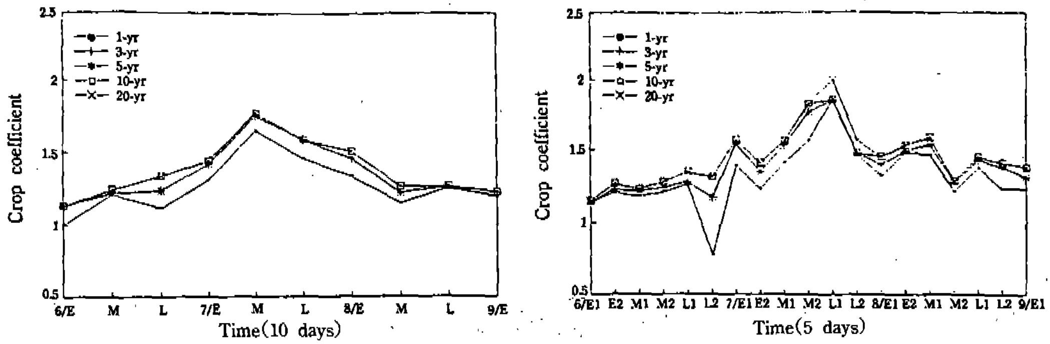
Southern part



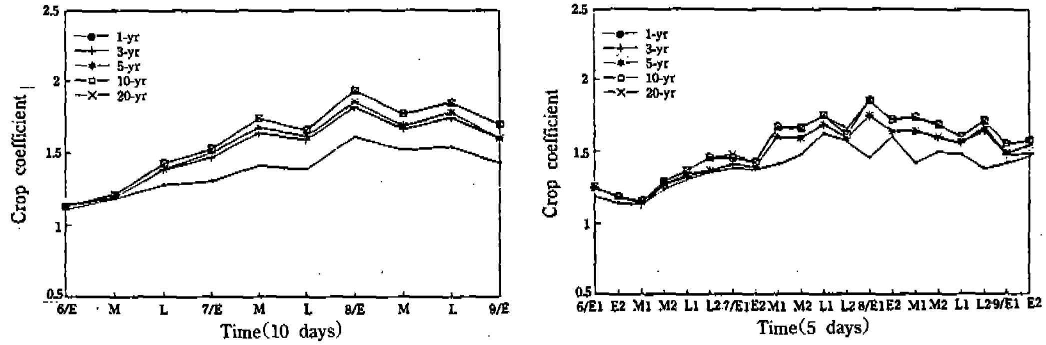
(a) (b)

Fig. 4. Probable ET with (a) 10 day and (b) 5 day intervals

Northern part



Middle part



Southern part

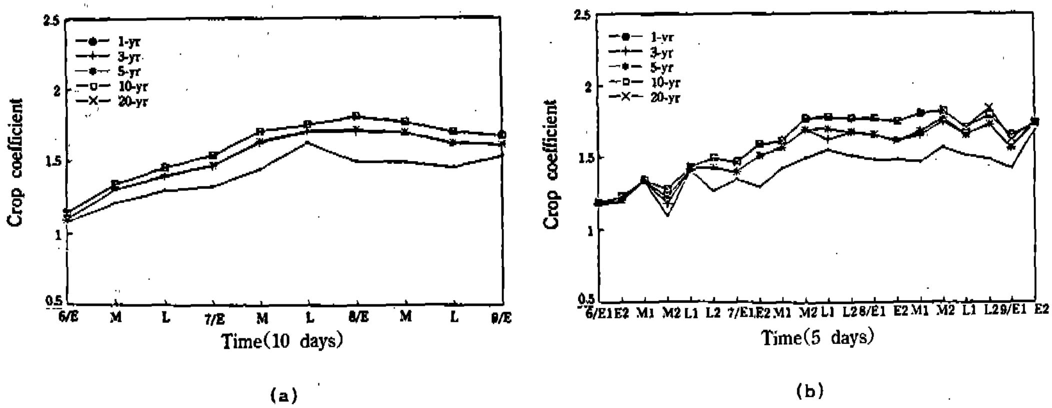


Fig. 5. Crop coefficient with (a) 10 day and (b) 5 day intervals

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