ESTIMATION OF CROP COEFFICIENT OF RICE AT RUPANDEHI DISTRICT OF NEPAL

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©Ontario International Development Agency ISSN: 1923-6654 (print)
ISSN 1923-6662 (online). Available at http://www.ssrn.com/link/OIDA-Intl-Journal-Sustainable-Dev.html

Abstract: This study is carried out to estimate the Crop coefficient (Kc) for Rice. A lysimeter is installed to estimate potential evapotranspiration (PET) at the experimental farm of Agricultural Research Center of Bhairahawa, which is located in western part of Nepal. The Blaney-Criddle formula is used to estimate the Kc for rice. The estimated values of Kc for rice at the four crop growth stages (initial, crop development, mid season/reproductive and late season/maturity) were 2.92, 1.85, 0.43 and 0.12. Average value of Kc for Rice is 1.33, which is estimated from measured crop PET and using temperature data. Aridity index (AI), the ratio of precipitation to PET, is an important parameter to determine the dryness of a region. The value of AI at the Rice growing season (August to November, 2010) in Bhairahawa is 1.16, and is classified as a more humid region.

Keywords: aridity index, crop coefficient, lysimeter, Nepal, Rice

INTRODUCTION

Rice (Oryza sativa L.)**,** the subject crop of this research, is a well-established component of Nepalese agriculture. Rice is the traditional stable food in Nepal, and can assure food security (at the family level, as well as at the national level). Rice cultivation and related occupations, provides the livelihood for many people living in the country. Rice can grow on soil types that are not well suited for other crops. Rice can grow in areas that are waterlogged or inundated. Rice can be stored for years and is relatively robust towards pests, and lowland rice is very robust towards weeds. One crop of rice can be raised in 3-4 months, well within the period of the monsoon rainfall. Rice yield is quite variable from farm to farm and from country to country. Many factors such as fertility of the soil, farm management practices, variety, prevalence of diseases and insects, and the weather are responsible for this variation (Robertson, 1975).

Rice has been associated with fields of standing water in various agro-ecological systems. Water use at field level is thus always high due to infiltration, percolation and spill. Therefore, rice is always blamed for a high consumer of water (between 900 mm and 2,250 mm per season) compared with other cereals (400 to 600 mm). Estimates of the water needs for productive and beneficial use in rice system can be divided in to three categories: (1) crop water requirement for evapotranspiration, (2) seepage and percolation and (3) needs for specific water management practices such as land preparation and drainage of water prior to the tillering stage. The range of daily dry season evapotranspiration rates is given as 5-12 mm/day, adding up to 500-1200 mm on the basis of 100 irrigated days. Evapotranspiration needs include two components: 1) transpiration for maintaining physiological processes that lead to plant development and growth, and 2) water needs to compensate for evaporation from the soil or water layer. Land preparation needs are in the order of 150-250 mm. Seepage and percolation needs of 2-7 mm/day are required if the moisture is to be kept at saturation (200-700 mm) level or if submerged conditions are to be maintained.

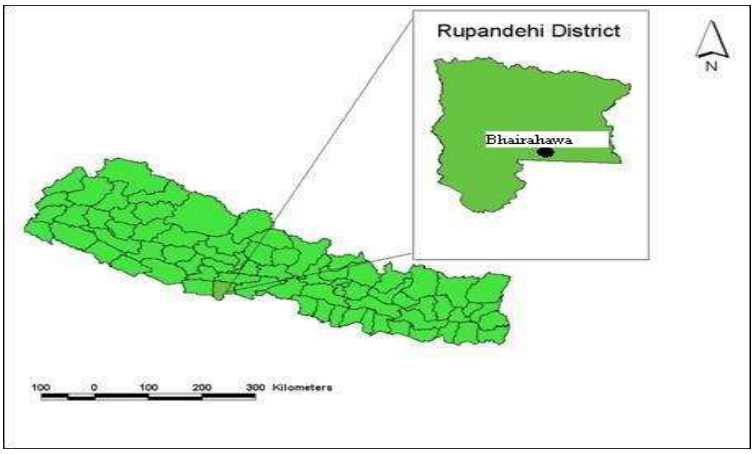

Figure 1: Location map of the study area in a Rupandehi district, Nepal

Figure 2: Lysimeter construction (a and b) and installation (c and d), Figure 2a. Making holes in B1, Figure 2b. Making a hole in B2, Figure 2c: Receiving Vessel and Figure 2d: Buckets (B1 and B2) with a pipe

If the drainage of water prior to the tillering stage is practiced another 50-100 mm are to be added. Based on these calculations, the total water requirements of irrigated rice ranges from 900 to 2,250 mm (Renault and Facon, 2004).

Terai is the store house of grains. However, unreliable and poor distribution of rain is one of the major causes for low yield of rice grains in the Rupandehi district (Bhandari and Kayastha, 2010). At present, farmers are opting for the production of this crop under irrigation. However, the water requirement data and crop coefficient of this crop is not locally available. Hence, knowledge of experimentally determined Kc value is important for proper irrigation scheduling and efficient water management of the selected crop variety. Therefore, this study was undertaken with the objective of developing crop coefficient for different growth stages of rice.

Crop coefficient represents crop specific water use and is essential for accurate estimation of irrigation requirement of different crops in the area. Although there are published Kc values for different crops, these values are commonly used in places where local data are not available. As these values vary from place to place and from season to season, there is a strong need for local calibration of crop coefficients under given climatic conditions (Tyagi et al., 2000).

The Kc is affected by a number of factors, which include: the type of crop, stage of growth of the crop and the cropping pattern (Allen and Smith, 1998). Doorenbos and Pruitt (1979) indicated that plant height and total growing season influence crop coefficient values. The higher the plant height and the longer the growing season the higher the crop coefficient values and vice versa.

MATERIALS AND METHODS

General description of the study area and experimental lysimeter

Rupandehi district, a part of Lumbini zone, is one of the seventy-five districts of Nepal.

The importance of this district lies in that Lumbini is the birth place of Lord Buddha and a major pilgrimage centre for Buddhist. This district lies in the western terai region of the western development region of Nepal as shown in Figure 1. Its area is 1360 $Km^{2.}$ It is situated between 27^0 20’ 00” to 27^0 47’ 25” N latitude and 83^0 12’ 16” to 83^0 38’ 16” E longitude. The elevation ranges from 100-300 metres and the total population is about 7, 08,419 (CBS, 2001). The monthly maximum temperature recorded of this district is 32.7^0C in May 1995 and June 1998. Similarly, the monthly minimum temperature recorded of this district is 13.7^0C in January 1993 and 1998. The average annual rainfall is 1709 mm. Loam and clay loam soil textures are the dominant soils of the area.

The experimental site is located at NWRP, Bhairahawa. It is situated between 27^o 32’ N latitude and 83^o 25’ E longitude. It is 105 m above the sea level. A lysimeter is made from readily available materials, plastic bucket with an area of 5811 square centimeter and 10 cm deep and is kept at one corner of the rice growing plot. The first bucket (B1) with tiny holes is completely filled with soil and leveled to the ground surface and holds rice and the second bucket (B2) with a hole is connected with a pipe to pass out the infiltrated water to the receiving vessel which is kept deep underground as in figure 2c. The receiver vessel kept underground and the B2 are connected with a water pipe so as to collect the percolated water.

Potential evapotranspiration (PET)

The measurement of PET includes the moisture evaporated to the atmosphere from plants and soil. As the soil and vegetation is confined within a small tank (the lysimeter) the measurements are made of the water **input**: Rainfall (**R**) and Additional water (**A**) and **output** (Percolated water **P**) collected in the receiving vessel, PET can be estimated from the equation below:

PET=R+A-P…………………… (i)

Determination of crop coefficient (Kc)

Kc is calculated by using the value of PET (as obtained in equation i) in a Blaney-Criddle formula (as in equation ii)

PET =2.54 Kc F ……… (ii)

and $F = \sum P_h\, T_f /100$,

where,

Kc = an empirical coefficient, depends on the type of the crop

P_h = monthly percent of annual day time hours, depends on the latitude of the place

T_f = mean monthly temperature in ^{o}F

F= sum of monthly consumptive use factors for the period

Figure 3: Plantation (a), crop development (b), mid season (c) and late season of Rice (d) Figure 3a: Plantation (1 August), Figure 3b. 30 days rice (31 August), Figure 3c: 60 days rice (October 11) and Figure 3d: 105 days rice (16 Nov)

Table 1: Average PET, AI and Kc

Days after plantation	**PET (cm)**	**AI**	**Kc**
Initial (31 days)	58.33	1.16	2.92
Crop development (30 days)	32.77	1.23	1.85
Mid season (28 days)	7.03	1.17	0.43
Late season (16 days)	1.60	0	0.12

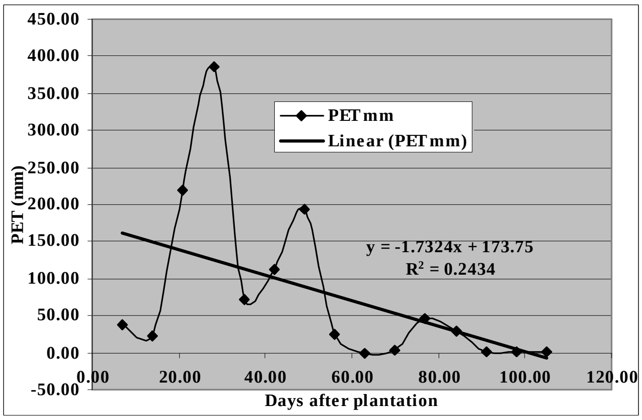

Figure 4a: PET of Rice

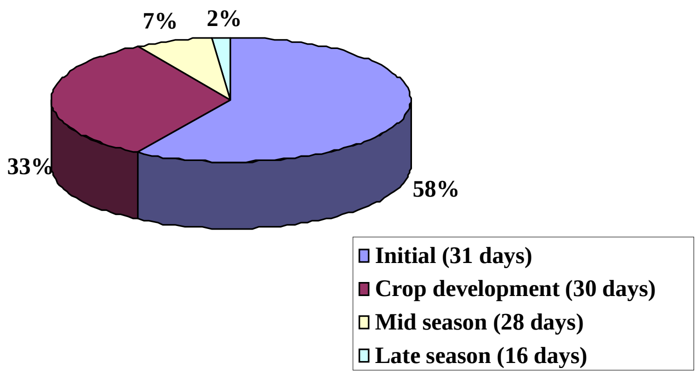

Figure 4b: Percentage of PET during the rice growing period

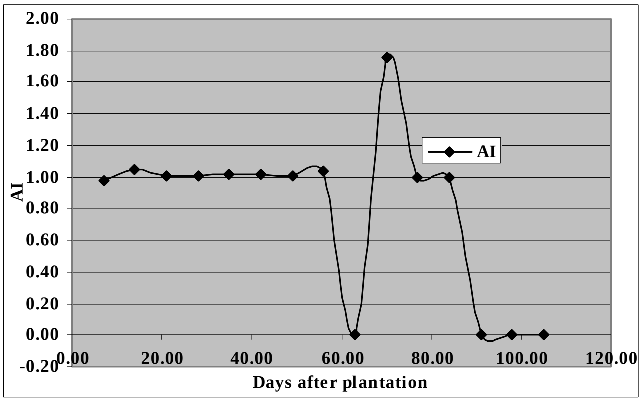

Figure 5: AI of Rice

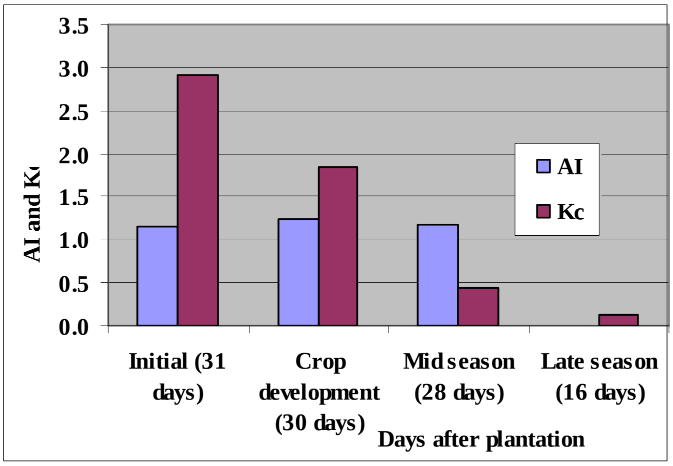

Figure 6: AI and Kc of Rice

Table 2: Agricultural parameters of rice grown on land and lysimeter

Parameters	Agricultural land		Lysimeter	
Hill		23		10
Tiller		130		97
Average plant height (cm)	(75,56,83,92,76)	76.4	(80,60,73,68,75)	71.2
Grains/ tiller	(93,90,44,60,110)	79.4	(48,120,90,60,80)	79.6
1000 grains weight (gm)		19.3		21.3

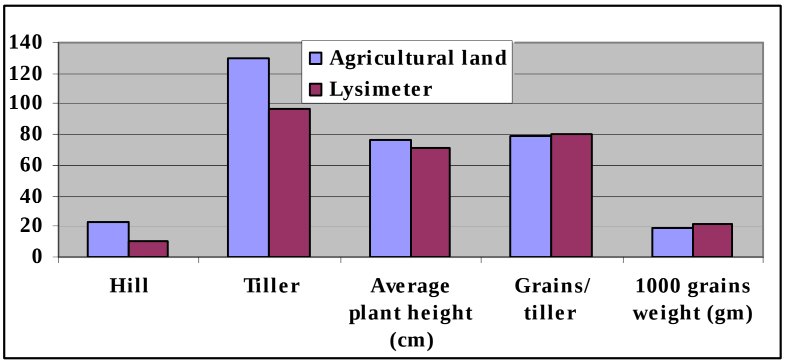

Figure 7: Comparison of different agricultural parameters of rice grown on land and lysimeter

Aridity Index (AI)

AI represents the severity of dryness of a region. Aridity is defined as the more or less repetitive climatic condition, which is characterized by a lack of water (Perry, 1986). It should be noted that aridity can be considered on seasonal or monthly basis (Coughlan, 2003). The AI ranges from 0.05 to 0.65 for the dry seasons. AI less than 0.65 correspond to Dry lands that, according to the United Nations Convention to Combat Desertification (UNCCD), may suffer desertification processes. So, AI should be greater than 1.15 during the rice growing seasons. In this study, UNEP aridity index (Hare, 1993) is used to estimate the AI which can be expressed as:

AI = P/PET………………………….. (iii)

where,

P=Precipitation in mm and PET=Potential Evapotranspiration in mm.

Crop detail

Before planting, the land is submerged with water and fully prepared for the plantation. The well known sabitri variety of rice in the area, NWRP, Bhairahawa, was planted on August 1, 2010 in and out of the lysimeter. The crop is harvested on November 17, 2010 (i.e. after 105 days of the plantation date). Recommended doses of fertilizers (Nitrogen: Phosphorous: Potassium is 80:40:20 kg/ha) is added to increase yield and obtain reasonable Kc. Some unnecessary plants grown were removed at the crop development period. Representative five plants were selected randomly from an area of agricultural land and compared with the plants of the lysimeter to calculate the differences in tiller, plant height, grains per tiller and 1000 grains weight.

Results And Discussion

PET is calculated using the water balance equation, Eq. (i) and is presented in Table 1. The total PET of the area for the season August to November in which rice is grown is 997 mm. Similarly, the total precipitation of the area for the season August to November (1 August to 16 November, 2010) is 1161.3 mm. Similarly, the total water added in a lysimeter to maintain sufficient moisture is 304 mm. Similarly, the total water percolated and collected in a bucket is 468 mm. It can be observed from the figure 4a and 4b that the PET of rice is maximum at the initial period and is minimum at the late season. 58 % of the PET is observed at the initial and only 2 % of the PET is observed in late season during the 105 days of rice growing period as shown in figure 2. The average temperature at different periods (initial, crop development, mid season and late season) is 29.63 ^{o}C, 28.80 ^{o}C, 26.89 ^{o}C and 24.25 ^{o}C respectively. Similarly, the average rainfall at different periods (initial, crop development, mid season and late season) is 675.3 mm, 403.7 mm, 82.3 mm. There has been observed no rainfall at late season. Therefore, high temperature and greater precipitation at the initial period has increased the PET and lower temperature and lower precipitation has reduced the PET at late season during rice growing period.

AI is obtained by dividing precipitation with PET (UNEP, 1992), Eq. (iii) and is presented in Table 1. It can be observed from the figure 5 that AI increases and decreases as increase in the days after plantation of rice and reaches to a maximum during late crop development stage and reduce significantly at a period before harvesting. The value of AI is 0 during the late season due to absence of rainfall during that period.

Crop coefficient values of rice are obtained by using the Blaney-Criddle formula, Eq. (ii) and are presented in Table 1. It can be observed clearly from the figure 6 that the Kc decreases with increase in the days after plantation of Rice. However, previous research results showed that Kc values varied by many factors such as location, season, crop development stage, irrigation methods, crop height, management etc (Baille, 1996).

The number of hill and tiller, plant height, number of grains per tiller and the weight of grains were analyzed. A greater number of hills, tillers and height of rice are observed in an agricultural land as shown in figure 7. The deep penetration of the rice roots at the land has favored the higher plant height in an agricultural land. However, the grains per tiller and 1000 grains weight are observed greater in lysimeter as shown in Table 2. Higher grains per tiller in a lysimeter were observed due to the regular preservation of sufficient moisture.

CONCLUSION

The PET of Rupandehi district for the season August to November in which rice is grown is 99.7 cm. The value of Kc for rice is 1.33 and the value of AI for rice is 1.16. High temperature and greater precipitation at the initial period of rice growing season has increased the PET and lower temperature and lower precipitation has reduced the PET at late season during rice growing period. AI increases and decreases as increase in the days after plantation of Rice and reaches to a maximum during late crop development stage and reduce significantly at a period before harvesting. Kc decreases with increase in the days after plantation of Rice. Higher grains per tiller in a lysimeter were observed due to the regular preservation of sufficient moisture. Thus, the increase in the rice yield has been observed due to the availability of sufficient moisture during the rice growing period from August to November.

ACKNOWLEDGEMENT

The authors would like to thank to the director of NWRP, Bhairahawa who gave permission to carry out this research. The author wishes to thank Mr. Ramesh Bhandari, Mr. Dayanidhi Pokharel and his assistants for their cooperation during the whole research period. Finally, I am grateful to my parents and family members for their encouragement and inspiration throughout the whole study.

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