International Journal of the Physical Sciences Vol. 6(1), pp. 15-26, 4 January, 2011
Available online at http://www.academicjournals.org/IJPS
DOI: 10.5897/IJPS10.683
ISSN 1992 - 1950 ©2011 Academic Journals

Full Length Research Paper

Climatic parameters and net irrigation requirement of crops

S. M. Shirazi[1]*, Z. Ismail[1], Shatirah Akib[1], M. Sholichin[1] and M. A. Islam[2]

[1]Department of Civil Engineering, Faculty of Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia.
[2]Department of Geology, Faculty of Science, University of Malaya, 50603 Kula Lumpur, Malaysia.

Accepted 04 January, 2011

The major meteorological data like temperature, relative humidity, rainfall, wind speed and sunshine hour for a period of 21 years was collected and analyzed. This was done for planning of irrigation strategy and to develop an appropriate irrigation scheduling for different cropping systems. Probability analysis, evapotranspiration and net irrigation requirement were estimated. For recurrence interval of 2, 5, 25, 50 and 100 years, the values of maximum rainfall found in June were 470, 660,790, 910, 982 and 104 mm, respectively. The highest ET_p (6.49 mm day^{-1}) was obtained in April and the lowest (3.68 mm day^{-1}) in July. The maximum net irrigation requirements for crops were found in the months of April, November, February, and January, respectively. May to September was the highest rainfall months when the rainfall was more than 300 mm in over 63.80% of the years and was always more than 50 mm. It appears that rainfall can be delayed upon during June and water resources can be brought into consideration to share the excess water for agricultural use in drought months. Effort was to be made to conserve for winter period as most of the month indicate drought by soil conservation. The results further indicate that net radiation generally decreased during monsoon reaching its minimum in December and then gradually increased again with the onset monsoon summer, finally reaching its peak in May. Latent heat flux ranges from a minimum of 213.52 ly/day in July to maximum of 387.83 ly/day in March.

Key words: Climate, irrigation requirement, crop production, energy and hydrological balance.

INTRODUCTION

Bangladesh is located in the subtropical Asia between 20°03' and 26°36 N latitude and 88°03' and 92°45' E longitude with a semi-humid climate. Location of the Mymensingh study area in Bangladesh is presented in Figure 1. The annual rainfall in the country ranges from 1400 to 5800 mm, but its distribution is uneven. Talukder et al. (1988) found that the average annual rainfall in Bangladesh was 2047 mm, the contribution of the month of June, July, August and September were 416, 415, 342 and 269 mm, respectively. Whereas, Ali et al. (1994) found that the average annual rainfall in the country was 2486 mm. They also found that the average monsoon rainfall in every year was found to be 66.76%. About 70 to 80% of the rainfall occurs during the month from June to September, leaving the most productive dry season (November to March) with extremely inadequate rainfall for crop growth. Also the month of April and May frequently have insufficient rainfall and crop suffer from significant period of drought. The efficacy of rainfall for crop production is dependent on its adequacy, certainty and distribution.

Long term rainfall probability analysis can provide a basis on which to plan cropping pattern and agronomic practices for more than 80% of cultivated land, which remain under rain fed agricultural. For planning an irrigation water supply system, the irrigation water requirement during different month of the crop growing period is a function of the rainfall deficit in those month. Thus, rainfall deficit information for different areas and periods can greatly help in determining optimum water release from reservoir/source in accordance with demand. The rainfall data is essential for planning and designing irrigation and surface drainage system, budgeting water use for optimum crop yield, selecting

---

*Corresponding author. E-mail: smshirazi@gmail.com.

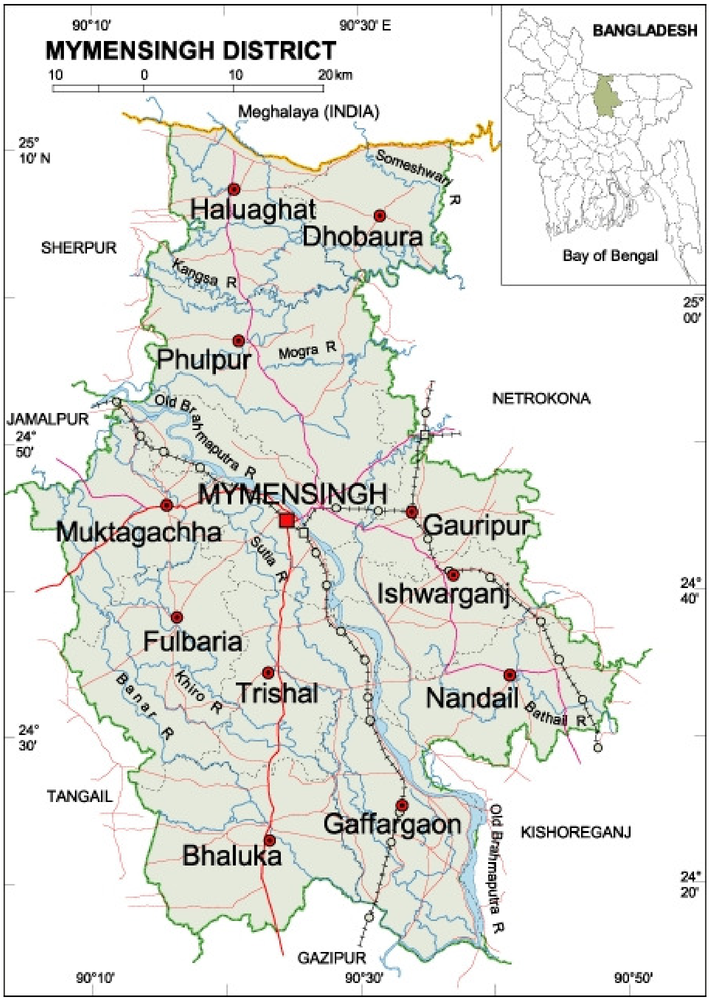

Figure 1. Location of the study area.

area for profitable rain fed farming and developing possible means for utilization of excess rainwater during monsoon season (Magali et al., 2003; Robart, 2003; Adeniran et al., 2010).

Radiation, temperature, precipitation, relative humidity and wind speeds are the major agro-climate factors responsible for evaporation from free water surface. Evaporation from a cropped soil is not only dependent on the meteorological factor but also on factors related to crop and to the available amount of soil moisture in the soil. Therefore, interest in obtaining evapotranspiration estimates and actual water use by different crops is increasing which would make irrigation scheduling and water budget analysis more meaningful. Average potential evapotranspiration (ET_p) varied from a minimum of 2.83 mm/day in December to a maximum of 5.79 mm/day in April throughout Bangladesh (Karim and Akhand, 1982). In another study, Talukder and Ali (1988) found that ET_p varied from 2.91 mm/day in December to 6.22 mm/day in April in Bangladesh. Probability analysis using past records can also provide knowledge concerning probable extremes and may solve many other hydrologic design problems (Claudio et al., 2010; Gouranga and Verma, 2005; Suxia et al., 2010). After the probability of occurrence of certain maximum rainfall or flood for which the hydraulic structure should be designed is determined, the proper design criteria can be found out.

Considering the urgency of this type of information twenty-one years meteorological data were collected for calculation of potential evapotranspiration, rainfall probability and net irrigation requirement of rice, wheat and potato. These information will provide a good ground for planning and implementation of small and large scale irrigation projects and various possibilities of utilizing excess rainwater in Mymensingh region. Solar radiation provides energy for evapotranspiration. Net radiation usually provides the upper limit for evapotranspiration especially in humid region. In the drier regions, evapotranspiration may exceed net radiation. Talukder

(1988) found that about 75 to 80% of the net radiation received at the surface is used for latent heat of evapotranspiration and the rest is used for soil heat flux and sensible heat flux.

Radiation and energy balances are vital to irrigation engineering, planners and water policy-making agencies dealing with soil-water plant atmospheric systems for reliable estimation of evapotranspiration of various crops. Hence, an attempt has been made to determine the radiation and energy balance and to assess the climate changes affecting crop production of the study area.

MATERIALS AND METHODS

Analysis of rainfall data

The average rainfall and its variability in each month were computed considering the data of the 21 years. Mean and standards deviation were calculated from these data and the percentage coefficient of variance were computed by the following formula:

$$\text{C.V (\%)} = \frac{Sd}{\overline{X}}100 \tag{1}$$

Where;

C.V = coefficient of variance
Sd = Standard deviation
$\overline{X}$ = Mean

The rainfall if any received during a month was classified according to Handa and Sreenath (1983) as > 300 mm, 200 to 300 mm, 100 to 200 mm, 50 to 100 mm and <50 mm.

Estimation of potential evapotranspiration

For estimating potential evapotranspiration Blaney and Criddle (1950) equation is given below:

$$\text{PET} = \frac{\sum t.p}{100} \tag{2}$$

Where, PET= Potential evapotranspiration
t= Temperature in °F
p= Monthly percent of day time hours

Incoming short wave radiation

Incoming short wave radiation (S_i) for the study area was calculated using the equation giving by Beriland (1960):

$$S_i = S_i(o)[1-(a+bn)n] \tag{3}$$

Where, $S_i(O)$ is the global radiation with cloudiness sky, 'b' is a coefficient and is equal to 0.38 for various latitudes, a is also latitudinal constant. Values of 'a' for study area are chosen as 0.351 for the latitude of 24°26' N. n is mean cloudiness in fractions of a unit and is equal to $1-S_{sun}$ where, S_{sun} is the ratio of actual sun hours over maximum sun hours.

Long wave net radiation

Long wave net radiation ($-L_i+L_u$) was calculated using the following equation:

$$(-L_i+L_u) = \sigma T^4[a+\beta\exp(-\gamma e)][1-\lambda_m(1-S_{sun})] \tag{4}$$

Where σ is Stephen-Boultzman constant and is equal to 5.67×10^{-8} W m^{-2} s^{-1} K^{-4}, T is the temperature in degree Kelvin, (273 + °C), a is 0.180, β is 0.250, γ is 0.218 m bar^{-1}, λ_m is 0.90, n is mean cloudiness in fraction of a unit ($1 - s_{sun}$) and e is actual vapour pressure, mbar.

Net radiation

Net radiation (R_n) was calculated using the

$$R_n = (S_i - S_u) - (-L_i + L_u) \tag{5}$$

Soil heat flux

Soil heat flux (S) was assumed to be 15% of the difference between actual and mean radiation and was computed using the relationship:

$$S = 0.15\left(R_n - \overline{R_n}\right) \tag{6}$$

Where, R_n and $\overline{R_n}$ are the actual and mean net radiation, respectively.

Latent heat flux

Latent heat flux (LE) for Mymensingh was calculated multiplying the values of latent heat of vaporization with potential evapotranspiration.

Latent heat of vaporization

Latent heat of vaporization (L) was computed using the equation:

$$L = 595.90 - 0.55T_c \tag{7}$$

Where T_c is the temperature in °C.

Sensible heat flux

Sensible heat flux (H) for Mymensingh was calculated using the equation:

$$H = R_n - LE - S \tag{8}$$

Putting the value of R_n, LE and S, sensible heat flux, H was calculated.

Radiation degree of dryness

Radiation index of dryness (RID) for Mymensingh was calculated using the equation development by Budyko (1948):

$$RID = R_n / LP \tag{9}$$

Where, R_n is the net radiation, ly day^{-1}, L is the latent heat of vaporization, cal gm^{-1} and P is the precipitation in mm day^{-1}

Growing degree days

Growing degree days (GDD) for Mymensingh region was calculated using the formula:

$$GDD = (T - T_t) \times N \tag{10}$$

Where, T is the mean air temperature, °C, T_t is the average minimum threshold germination temperature, °C and N is the number of day in respective months, T_t was taken to be 5°C.

Probability analysis of rainfall data

The most commonly used Weibull (1939) formula was used for probability analysis. Data were arranged in descending order of magnitudes, starting from the highest values .The values of return period, T, were computed from the corresponding rainfall data using the following formula:

$$T = \frac{(n+1)}{m} \tag{11}$$

Where,
T = Return period
n = Total number of years
m = Order or rank of values

The percentage probability of rainfall was also calculated using the formula:

$$P = \frac{1}{T}100 \tag{12}$$

Where,
P = Percent probability
T = Return period

Estimation of evapotranspiration (ET)

Evapotranspiration was estimated following Blaney-Criddle (1950) method. This method was stated as most suitable and accurate among the eleven methods compared by Talukder and Ali (1988):

$$ET_{crop} = K_c ET_p = E_c \sum \frac{Pt}{100} \tag{13}$$

Where,
ET_p = Potential evapotranspiration
P = Monthly percent of day lime hour
T = Temperature, °F
K_c = Crop coefficient taken from Doorenbos and Pruitt (1977)

Net irrigation requirement

The net irrigation requirement was calculated using the field water balance equation (Doorenbos and Pruitt, 1977) as follows:

$$\ln = ET_{crop} - (P_e + G_e + W_b) \tag{14}$$

Where,
In = Net irrigation requirement
ET_{crop} = Evapotranspiration of crop
P_e = Rainfall
G_e = Ground water contribution, it any
W_b = Stored soil moisture al the beginning of each period

For rice, the G_e and W_b are considered negligible, as rice is usually grown in standing water regimes. Therefore, the net irrigation requirement of rice was calculated using only ET and 80% dependable rainfall (Karim and Akhand, 1982), On the other hand, considering 100% dependable rainfall, net irrigation requirement of wheat and potato crops were estimated.

RESULTS AND DISCUSSION

The average rainfall received during the period of 21 years at Mymensingh region for each month of the year along with total for the year and percentage coefficient of variances are given in Table 1. Maximum rainfall occurred in July and minimum in January at Mymensingh region which are 487 and 93 mm, respectively. The variability of rainfall as measured by the percent coefficient of variance for different months varied from 38.50 to 176.00 at this region. For mean monthly rainfall the highest C.V was observed in November (176%) and the lowest (38.50%) in July. The average annual rainfall was 2387.20 mm. The frequency distribution of months according to category of rainfall received during the 21 years period is presented in Table 1. During the 21 years period of study there was rainfall in only 9th of January and December, 10th November, 13th of February, 16th of March and all the 21st April, May, June, July, August, September and October months. Thus, the probability of rainfall during the difference months was 0.43 for January and December, 0.48 for November, 0.62 for February, 0.76 for March, and 1.0 for April to October months.

However, rainfall during the month of December to February was always less than 50 mm and 50 to 60% of times it was even less than 5 mm. As such, these months cannot be considered to have generally any significant role in the crop production. The rainfall during October had a frequency of 3 for more than 300 mm. 7 for 200 to 300 mm, 6 for 100 to 200 mm and the rest 2 for 50 to 100 mm. This rainfall could be of some use for Rabi (October to March) sowing. May to September were the highest rainfall months when the rainfall was more than 300 mm in over 63.8% of the years and was always more than 50

Table 1. Mean monthly rainfall and its frequency distribution as per the category of rainfall at Mymensingh.

Month	Frequency distribution								C.V
	Above 300 mm	200 to 300 mm	100 to 200 mm	50 to 100 mm	Below 50 mm	Total rainy month	Probability of rainfall	Mean	(%)
Jan	-	-	-	1	8	9	0.43	9.30	158.70
Feb	-	-	1	2	10	13	0.62	21.60	150.90
March	-	-	2	4	10	16	0.76	34.60	102.10
April	1	2	9	4	5	21	1.0	125.50	74.62
May	12	5	3	-	1	21	1.0	377.80	48.54
June	14	5	2	-	-	21	1.0	453.30	48.45
July	18	2	-	-	1	21	1.0	487.00	38.50
Aug	11	6	4	-	-	21	1.0	322.40	38.56
Sep	12	7	2	-	-	21	1.0	326.90	38.85
Oct	3	7	6	2	3	21	1.0	195.00	66.05
Nov	-	-	1	2	7	10	0.48	20.10	176.00
Dec	-	-	-	2	7	9	0.43	13.70	163.64
Total	-	-	-	-	-	-	-	2387.20	-

mm while May and June could be useful for Kharif (April to September) sowing, but the harvest may have to be postponed up to October.

Distribution of rainy days over the months

The results on the distribution of rainy days over the months based on 21 years period for Mymensingh are presented in Table 2. The choice of crops depends less on the rainfall received during the month than on its distribution which can be better studied with the help of the number of rainy days and the average rainfall received on a rainy day.

A rainfall less than 5 mm in a day with no rainfall on the previous or next day was considered a little use. Such rainfall was ignored, except for the purpose of total rainfall arriving at the rainy days.

The results indicated that the number of rainy days per year were 87.33 that is 1 out of 4 days and or little more. The maximum number of rainy days per month was in July and 16.19. The maximum rainfall per rainy days was in October (34.42 mm), followed by May (30.54), July (29.64) and June (29.48). The rainfall per rainy days during the month of January (12.99 mm), February (13.90 mm), March (20.10 mm), April (20.48 mm), October (34.42 mm), November (23.36 mm), and December (21.62 mm) was sufficient but their duration was short (6.38 to 0.53 day/month). This together with the previous observation showed that beside the month of June to September the rainfall received during October to February would be considerable enough to be of advantage for crop production.

Further, the rainfall per rainy day, which varied from 21.62 to 34.42 mm during the period of June to December, and number of rainy day per month would be of importance to crop planning during the period.

Drought, normal and abnormal months

At Mymensingh it was observed that the rainfall during September was mostly normal with only 5 out 21 months turning out to be abnormal only (Table 3). More than 50% of April, May, August and October were normal, 9th of April, and 7th of October out of 21 months were drought, 10th of may, 13th of June, 14th of July and 8th of August out of 21 months were abnormal. Thus, the months of May to September can generally be relied upon for the amount that was abnormal. Thus, the month of May to September can be generally relied upon for amount of rainfall to be received.

The month of June, which is of importance from the point of view of Kharif sowing showed that it went abnormal in 13 out of 21 years, none were in drought and could have done much damage due to generally higher rainfall during this month. It appears that rainfall can be relayed upon during

Table 2. Number of rainy days and average rainfall per rainy day in each of the calendar months at study area.

Month (1)	Total number of rainy days (2)	Average rainy day/month (3)	Rainfall/rainy day (mm) (4)	Average rainfall/rainy day (mm) (col. 2 x col. 4)
Jan	12	0.57	12.99	155.900
Feb	25	1.19	13.90	347.850
Mar	34	1.62	20.10	653.506
Apr	134	6.38	20.48	2743.900
May	263	12.52	30.54	8031.128
Jun	313	14.90	29.48	9227.568
Jul	340	16.19	29.64	10077.600
Aug	287	13.67	24.92	7150.610
Sep	279	12.29	25.25	7045.936
Oct	119	5.67	34.42	4095.852
Nov	17	0.81	23.36	397.152
Dec	11	0.53	21.62	237.820
Total	1834	87.33	-	50194.822

Table 3. Distribution of months as per drought, normal and abnormal at Mymensingh.

Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1987	a	a	a	b	b	c	c	c	c	b	a	a
1988	a	a	a	a	b	c	c	c	c	a	a	a
1989	a	a	a	b	c	c	b	b	b	b	a	a
1990	a	a	a	b	c	c	c	b	b	a	a	a
1991	a	a	a	a	b	b	c	c	b	b	a	a
1992	a	a	a	a	c	b	b	c	b	b	a	a
1993	a	a	a	b	a	b	c	b	b	a	a	a
1994	a	a	a	b	b	c	c	b	b	a	a	a
1995	a	a	a	a	c	b	b	c	b	b	a	a
1996	a	a	a	a	c	c	c	b	b	b	a	a
1997	a	a	a	b	c	c	b	b	c	a	a	a
1998	a	a	a	b	b	b	c	b	c	b	a	a
1999	a	a	a	a	c	b	c	c	b	a	a	a
2000	a	b	a	a	c	c	c	b	b	b	b	a
2001	a	a	a	b	b	b	c	b	b	b	a	a
2002	a	a	a	a	c	c	c	b	b	b	a	a
2003	a	a	a	b	c	c	b	b	c	b	a	a
2004	a	a	a	a	b	b	c	b	c	b	a	a
2005	a	a	a	b	b	c	b	b	b	b	a	a
2006	a	a	b	b	c	c	a	c	b	b	a	a
2007	a	a	a	a	b	c	c	c	b	a	a	a

a = drought, b = Normal and c = abnormal.

June and Water resources can be brought into consideration to share the excess water for agricultural use in drought months. Efforts should be made to conserve for Rabi period as most of the months indicated drought by soil conservation.

Radiative index of dryness

Radiative index of dryness (RID) is given in Table 4. Met radiation received at the surface was low beginning from December to May and vice-versa. Similarly, amount of

Table 4. Radiation index of dryness (RID) and growing degree days (GDD) for Mymensingh region.

Month	Rn (ly/day)	L (call/gm)	Precipitation (mm/day)	RID	Mean air temperature (T°C)	GDD
Jan	204.62	585.85	0.30	11.64	18.27	411.37
Feb	259.17	584.63	0.77	5.76	20.50	434.00
Mar	306.26	582.24	1.12	4.7	24.83	614.73
Apr	348.29	581.15	4.18	1.43	26.81	657.30
May	356.98	580.79	12.19	0.50	27.47	696.57
Jun	272.72	580.22	15.11	0.31	28.51	705.30
Jul	292.24	580.23	15.71	0.32	28.50	728.50
Aug	282.72	580.12	10.40	0.47	28.70	734.70
Sep	263.25	580.36	10.90	0.42	28.30	699.00
Oct	263.78	581.16	6.90	0.72	26.80	675.80
Nov	208.42	582.88	6.29	5.33	23.68	560.40
Dec	184.57	585.86	0.44	7.17	19.17	439.27

precipitation that fills the surface was low in winter, gradually increased in summer and was high in monsoon. Due to this, systematic variation in net radiation and precipitation, RID was high from November through January. The values then generally decreased from February to March. It is clear from the above results that irrigation was necessary in Bangladesh during winter and partly in summer and autumn for successful crop production when precipitation is not sufficient to supply adequate moisture into the soil. On the other hand, during monsoon, precipitation was so high that flood occurred causing enormous damage to crop.

Growing degree days

Table 4 shows the growing degree-days (GDD) for Mymensingh regions. The results indicate low growing degree days in winter ranging from 411.37 to 439.27 and high in summer, monsoon and autumn ranging from 560.40 to 734.70. However, GDD was low in winter, crop can be successful, minimum and maximum GDD of 411.37 and 734.70 were observed in January in August, respectively. It appears from the results that although GDD was low in winter, crop can be successfully grown in this season. Only those crops that can neither withstand water logging nor water can be grown in these seasons.

Components of radiation balance

Components of radiation balance at the surface as incoming short wave radiation (global), S_i out going short wave radiation (albedo), S_u long wave net radiation ($-L_i+L_u$) and net radiation, R_n for Mymensingh are demonstrated in Figure 2. The largest term in the balance was S_i (the incoming short wave radiation) that raged between winter and summer month from about 380 to 574 ly/day. The results indicated that the lowest S_i was observed in December and the highest in April. It is assumed that 20% of the incoming short wave radiation was reflected from the surface as outgoing short wave radiation; Su assumed made is in agreement with Aslyng (1965) who reported about 22% autumn.

Results showed that the highest long wave net radiation, ($-L_i+L_u$) was observed to be 119.87 ly/day in December and the lowest was 59.42 ly/day in June. Net radiation, R_n received at the surface at Mymensingh varied from a minimum of about 356.98 in May. The results further indicated that R_n generally decreased during monsoon reaching to its minimum in December and then gradually increased again with the onset of summer, finally reaching to its peak in May.

Component of energy balance for potential evapotranspiration

Component of energy balance as soil flux, S, latent heat flux, LE, and sensible heat flux, H, for the study area are shown in Figure 3. Outward soil heat flux, S, was observed from August to February, whereas, inward soil heat flux was observed from March to July. Highest and lowest outward, S was observed in May and June, respectively. Latent heat flux ranged from a minimum of 313.52 ly/day in July to a maximum of 387.83 ly/day in March. Generally, evapotranspiration, ET of well watered crops with full cover nearly equaled net radiation, Rn out ward flux of H was found from October to May and the rest of the months were the inward flux.

Water balance in the study area

Figure 4 depicts the water balance analysis for Mymensingh region. It appears from the results that during January to April and November to December,

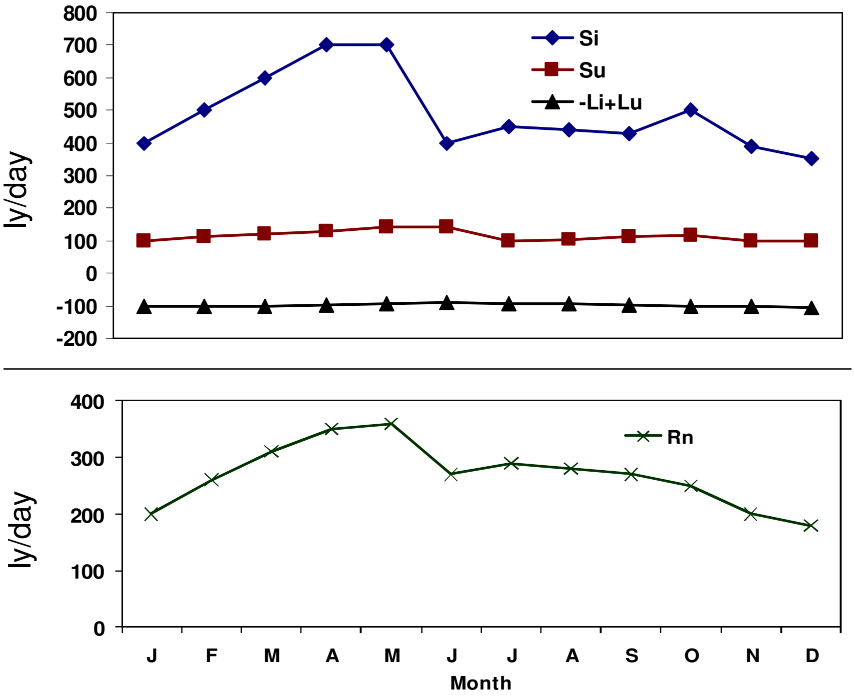

Figure 2. Radiation balance components at the surface at study area.

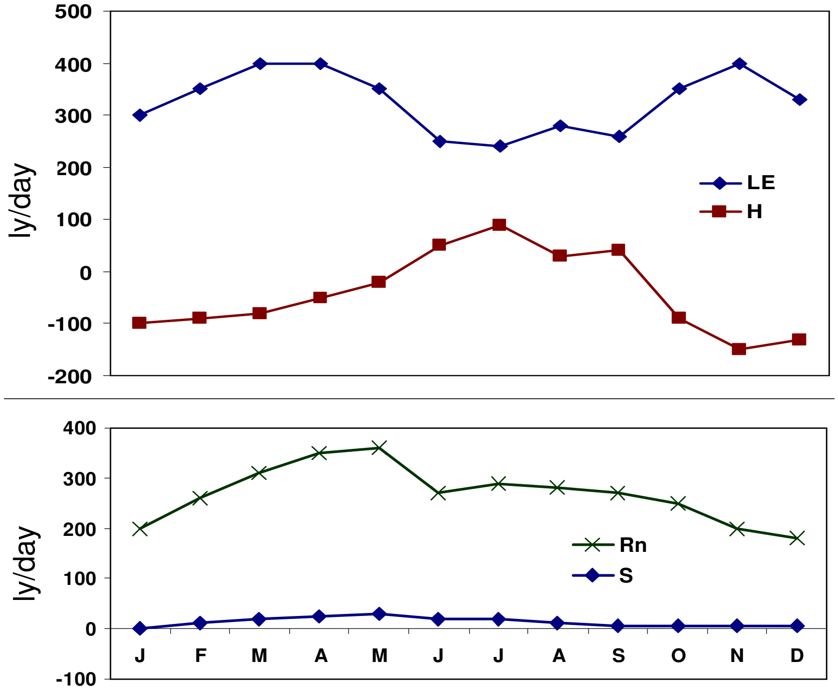

Figure 3. Energy balance components at the surface at study area.

potential evapotranspiration, ET_p, was higher than precipitation. It appears from the above results that irrigation was necessary in order to grow crops during these periods because of non-availability of sufficient amount of rainwater and high atmospheric evaporative demand by crops. At the rest of the period beginning from

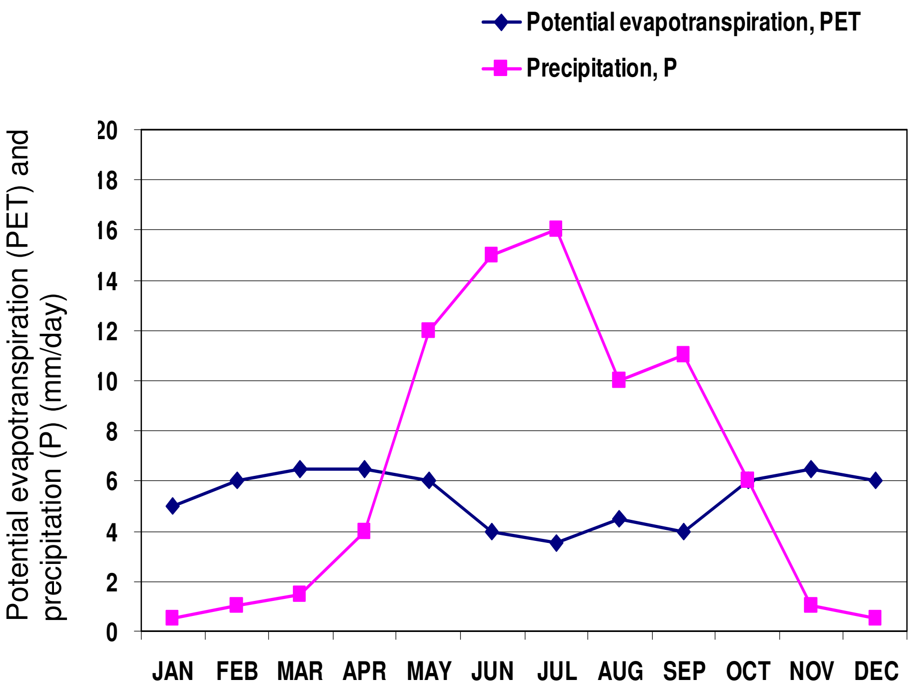

Figure 4. Hydrological balance of PET and precipitation at Mymensingh.

Table 5. Rainfall probability and recurrence interval of rainfall (mm) of difference month of the year at Mymensingh region.

Month	Probability						Recurrence interval (years)					
	10	20	40	50	80	90	2	5	10	25	50	100
January	15	12	10	0	0	0	8	12	15	17	19	20
February	80	50	7	22	0	0	0	50	80	114	135	155
March	98	70	37	140	48	0	22	70	98	124	142	158
April	285	235	470	370	185	0	140	235	285	335	370	400
May	655	556	425	470	265	82	370	556	655	760	826	889
June	790	680	535	530	345	155	470	680	790	910	982	1048
July	750	665	551	340	190	260	530	665	750	840	902	952
August	565	486	383	300	111	110	940	486	565	648	703	751
September	570	478	353	210	64	25	300	478	570	670	732	793
October	432	354	253	0	0	0	210	354	432	514	506	613
November	88	41	0	0	0	0	0	41	88	140	173	202
December	59	32	0	0	0	0	0	32	59	87	103	112

May to the middle of October, precipitation was much higher that ET_p in this period varied from 3.68 to 5.98 mm/day, whereas, precipitation varied from 6.29 to 15.71 mm/day.

The results showed that an abundant supply of precipitable water during this period might cause sudden flood, which in turn might damage crops. This is in fact called for immediate withdrawal of water and control of water level to a certain height for successful crop production.

Rainfall probability

The probability levels of 10, 20, 40, 50, 80 and 90% and the values of rainfall at recurrence intervals of 2, 5, 10, 25, 50, 100 years in different months of the year in Mymensingh region are presented in Table 5. The maximum values of rainfall at Mymensingh region was in the magnitude of 790, and 680 mm at 10 and 20% probability levels in June and 551, 530, 345 and 260 mm in July at 40, 50, and 90% probability levels, respectively

Table 6. Average monthly potential evapotranspiration for Mymensingh region.

Month	Temperature		Percent day time hours	ET_p in month	ET_p mm/day	Percent day time hour	ET_p mm/day
	(°C)	(°F)	P (actual- data)		(based on real data)	P (based on latitude)	(based on latitude)
January	18.27	64.97	10.1	6.49	5.32	7.55	4.01
February	20.5	68.9	9.69	6.68	6.06	7.14	4.46
March	24.83	76.7	10.22	7.85	6.43	8.39	5.27
April	26.81	8026	9.56	7.67	4.49	8.62	5.86
May	27.47	81.45	9.97	7.3	5.68	9.33	6.22
June	28.51	83.32	5.6	4.67	3.95	9.23	6.51
July	28.5	83.3	5.37	4.47	3.68	9.43	6.44
August	28.7	83.66	6.5	5.44	4.46	9.08	6.22
September	28.3	82.96	5.61	4.65	3.94	8.31	5.84
October	26.8	80.24	8.98	7.2	5.9	8.08	5.31
November	23.68	74.62	10.14	7.56	6.4	7.41	4.68
December	19.17	66.51	10.4	9.62	5.67	7.43	4.05

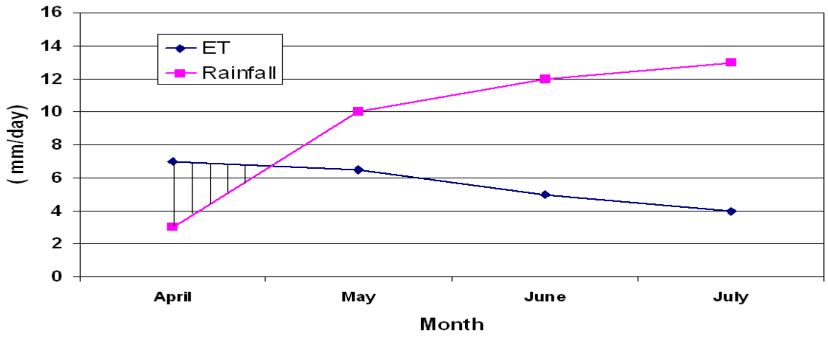

Figure 5. Net irrigation requirement of Aus paddy.

(Table 5). Considering the recurrence interval, the maximum rainfall was found to be 530 mm in July but 680, 790, 910, 982 and 1098 mm was found in the month of June, respectively. The minimum values of rainfall were found in January in respect of the above-mentioned probability and recurrence intervals. It can be seen that maximum and minimum values of rainfall obtained were similar with respect to time for both cases. The findings are in conformity with the results of Hossain et al. (1986).

The results clearly indicated that the magnitude at different probability levels were different compared to recurrence intervals. The above magnitude of rainfall would help in planning the crops lo be grown, irrigation, drainage, storage of water and other facilities to be created for successful agricultural operations in Mymensingh region.

Potential and actual evapotranspiration

Potential evapotranspiration (ET_p) is presented in (Table 6) based on Blaney-Criddle (1950) method. The highest PET (6.49 mm day) was obtained in April and the lowest 3.68 mm day 11 in July. The maximum rainfall (15, 71 mm day^{-1}) occurred in July and minimum (0.30 mm day^{-1}), in January. These results have some deviations with the results presented by Karim and Akhand (1982). PET of different months was also determined based on latitude; some small differences were found in the values of PET between the real data and data based on latitude, because climate was not considered in latitude while all climatic data were considered as actual data.

Net irrigation requirement of rice, wheat and potato

It was observed that irrigation was needed at the first month of Aus paddy. At later stages, no irrigation is necessary rather there was surplus rainwater (Figure 5), Supplemental irrigation was required at the later stage of Transplant Aman paddy and irrigation should be ensured in the last two months (Figure 6). Boro paddy required irrigation of almost similar amount throughout the growing season but a little bit higher irrigation was needed in

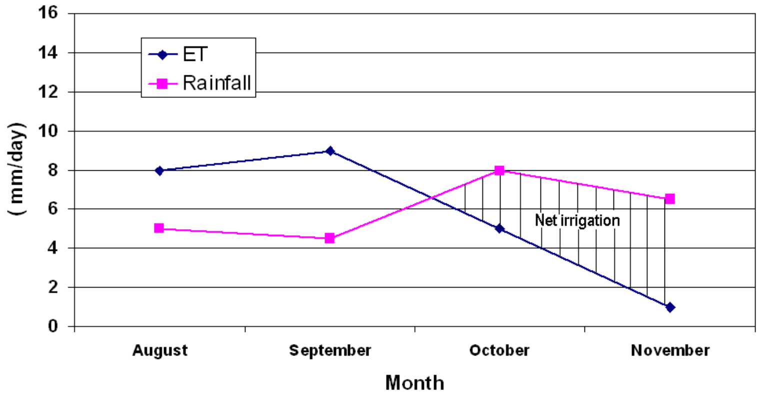

Figure 6. Net irrigation requirement of transplant Aman paddy.

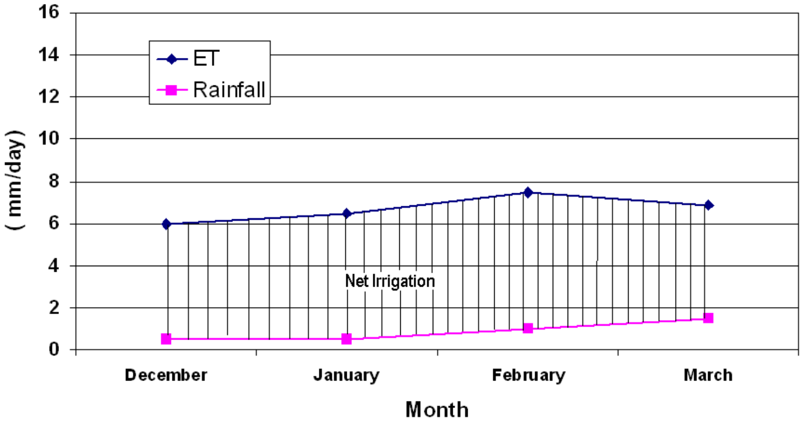

Figure 7. Net irrigation requirement of Boro paddy.

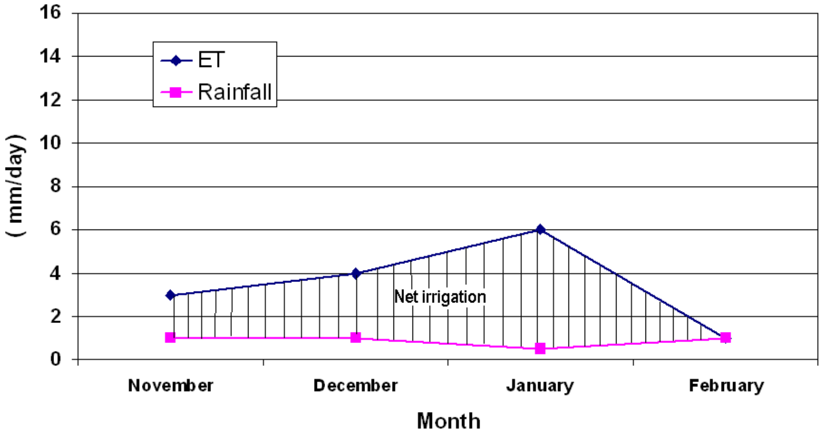

Figure 8. Net irrigation requirement of wheat.

reproductive stage (Figure 7). Wheat and Potato required considerably less amount of irrigation water than Boro paddy throughout the growing season although it was observed that at later stage irrigation requirement was higher for both the crops wheat and potato (Figures 8 and 9).

Conclusions

Present study carried out to estimate the radiation, energy, and hydrological balance for assessing the climate changes affecting crop production of the study

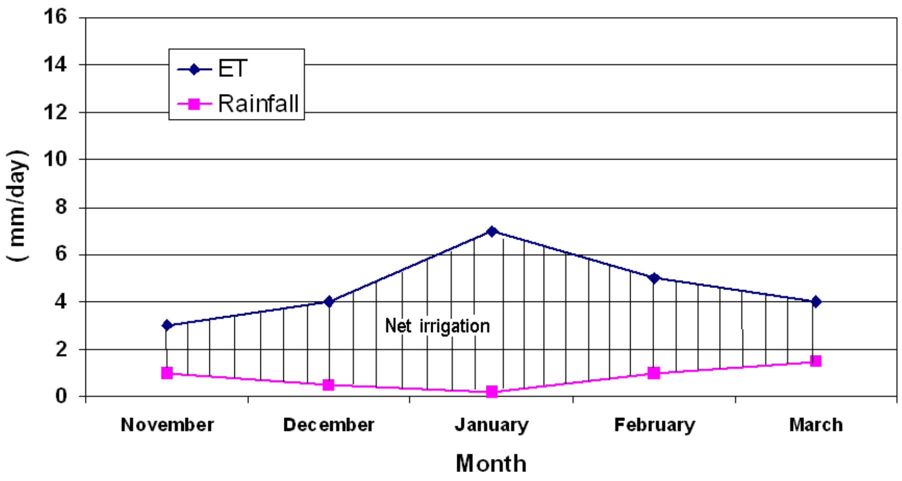

Figure 9. Net irrigation requirement of potato.

area. The major climate parameters, namely, rainfall, temperature, humidity, wind speed and sunshine hour were collected and analyzed. The highest potential evapotranspiration was obtained in April and lowest in July. The maximum net irrigation requirement for crops is December to February. Net radiation gradually decreased during monsoon season. Latent heat flux is minimum in July and maximum in March.

ACKNOWLEDGEMENT

Financial support by the Institute of Research Management and Monitoring (IPPP), University of Malaya (UM) under UMRG research grant number RG092/10SUS is gratefully acknowledged.

REFERENCES

Adeniran KA, Amodu MF, Amodu MO, Adeniji FA (2010). Water requirements of some selected crops in Kampe dam irrigation project. Australian J. Agric. Eng., 1(4): 119-125.

Ali MM, Ahmed M, Talukder MSU, Hye MA (1994). Rainfall distribution and agricultural droughts influencing cropping pattern at Mymensingh region. Progr. Agric., 5(2): 197-204.

Aslyng HC (1965). Evaporation, evapotranspiration and water balance investigation at Copenhagen. Acta Agric. Scand., 9(3-4): 284-300.

Beriland TG (1960). Methods of climatologically computation of total incoming solar radiation. Meteorol. Gidrol., 6(9-12): 12.

Blaney HF, Criddle WD (1950). Determining water requirements in irrigated areas from climatological and irrigation data. USDA Soil Conserv. Serv. Tech. pap., 96: 48.

Budyko MI (1948). Evaporation under natural condition. Isr. Program. Sci. Transi. Jeuralim., 16: 2-17.

Claudio OS, Roger LN, Stewart H, Jay B, Gary G, Rick B, Mathew W, Chad K (2010). Assessment of climate change impact on Eastern Washington agriculture. Clim. Change, 102: 77–102.

Doorenbos J, Pruitt WD (1977). Crop water requirements. Irrigation and Drainage Paper No 24 FAO Rome. Italy.

Gouranga K, Verma HN (2005). Climatic water balance, probable rainfall, rice crop water requirements and cold periods in AER 12.0 in India. Agric. Wat. Manage., 72: 15–32.

Handa DP, Sreenath PR (1983). Some statistical studies on rainfall pattern of Jhansi. Indian J. For., 6: 222-227.

Hossain MA, Mridha MAK, Razzak MA, Khatun A (1986). Some studies on rainfall pattern of Bangladesh. Project Report, Department of Irrigation and water Management, Bangladesh Agricultural University. Mymensingh.

Karim Z, Akhand NA (1982). Net irrigation requirement of rice and evapotranspiration of wheat and potato for different location of Bangladesh, Soil and irrigation Division, Publication No. 11, Bangladesh Agricultural Research Council, Farm Gate, Dhaka.

Magalı´ G, Dirk R, Sven-Erik J (2003). Evapotranspiration analysis and irrigation requirements of quinoa (*Chenopodium quinoa*) in the Bolivian highlands. Agric. Wat. Manage., 60: 119–134.

Robart JH (2003). The effect of climate change on global potato production. Am. J. Potato Res., 80: 271-280.

Suxia L, Xingguo M, Zhonghui L, Yueqing X, Jinjun J, Gang W, Jeff R (2010). Crop yield responses to climate change in the Huang-Huai-Hai Plain of China. Agric. Wat. Manage., 97: 1195–1209.

Talukder MSU (1988). Radiation and energy balance from standard metrological observations in Bangladesh. J. Inst. Eng. Bangladesh, 15(1): 17-22.

Talukder MSU, Ali SMA (1988). Comparison of different methods for estimation of evapotranspiration. Bangladesh J. Agric. Sci., 15(1): 59-64.

Talukder MSU, Ali SMA, Haq MM, Hossain MA (1988). A study on rainfall pattern of Bangladesh. Bangladesh J. Agric. Sci., 15(2): 217-224.

Weibull W (1939). A statistical theory of the strength of materials. Ing. Vetenkap Handi (Stockholm), Sweden.