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Reference crop evapo-transpiration (ET_0) over Bangladesh and its implication in crop planning

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Abstract

An accurate estimate of crop water requirement is of vital importance in planning, design and operation of irrigation and water resources system. Relationships between the evapo-transpiration of a pre-selected crop (the reference crop), which is referred to as reference evapo-transpiration (ET_0), and other crops are established by multiplying ET_0 by crop coefficients. The Penman-Monteith (P-M) equation with its new definition of ET_0 is recommended by FAO as the standard method of crop water requirement calculation. Using 54 years climatic data, the ET_0 for different regions of Bangladesh were calculated with FAO CROPWAT software. The implication of the ET_0 values in crop planning are discussed.

Key words: Penman-Monteith equation, Reference evapotranspiration, CROPWAT, Crop planning

Introduction

The estimation of crop water requirement is one of the principal steps in the planning, design and operation of irrigation and water resources systems. Crop water requirements vary with crop characteristics and local condition. Relationships between the evapotranspiration of a pre-selected crop (the reference crop), which is referred to as reference evapotranspiration (ET_0), and other crops are established by multiplying ET_0 by crop coefficients. The former depends on local meteorological conditions, whereas the latter depends on crop characteristics, time of planting or sowing and stage of crop development. Little information is available in Bangladesh regarding ET_0 values at location specific and year around. The objective of this paper is to determine ET_0 for different regions of the country and to interpreting the same in crop planning.

ET_0 predicting models range from deterministically-based combined energy balance-vapor transfer approaches to empirically relationships based on climatological variables, or to evaporation from a standard evaporation pan. Updated procedures for calculating ET_0 were established by FAO. According to FAO-1992 (Smith *et al.*, 1992), Penman-Monteith (P-M) method gives more consistent ET_0 estimates and has been shown to perform better than other ET_0 methods when compared with lysimeter data. Now-a-days, the FAO CROPWAT software, which is based on P-M equation, is widely used to calculate ET_0. Hence, the same was used in this study to calculate ET_0.

Materials and Methods

Selection of Meteorological Stations and Data Collection

Seven different stations located at different representative regions (and also different agro-ecological zones) of the country were selected for study. Their locations are specified in Fig. 1. The stations were namely: Mymensingh (24 ^{0} 43″ N, 90 ^{0} 26″ E, and 19 m above Mean Sea Level, MSL), Pabna (24 ^{0} 8″ N, 89 ^{0} 3″ E, 34 m above MSL), Rangpur (25 ^{0} 45″ N, 89 ^{0} 15″ E), Rajshahi (24 ^{0} 24″ N, 88 ^{0} 48″ E), Comilla (23 ^{0} 20″ N, 91 ^{0} E), Khulna (22 ^{0} 47″ N, 89 ^{0} 32″ E.) and Chittagong (22 ^{0} 16″ N, 91 ^{0} 30″ E).

Monthly mean data of different climatic elements for the period from 1948 to 2001 were used in this study. Data were collected from Bangladesh Meteorological Department for the station Mymensingh, Pabna, Khulna, Rajshahi and Chittagong; and for Comilla and Rangpur stations, data were taken from 'Agricultural Statistical Yearbook of Bangladesh' (BBS, 1976, and later publications).

Calculation of ET_0

The ET_0 values were calculated using FAO CROPWAT 4, windows version 4.2. 'CROPWAT' is a computer program for irrigation planning and management (Clarke, 1998). It includes a revised method for estimating reference crop evapotranspiration (ET_0), adopting the approach of Penman-Monteith as recommended by the FAO Expert Panel (Consultation held in May, 1990 in Rome) (Smith *et al.*, 1992). Details on the methodology of 'CROPWAT' can be found in the irrigation and Drainage Paper No. 56, "Crop Evapotranspiration" (Allen *et al.*, 1998). The parameter angstrom coefficients, a_s and b_s for solar radiation estimation, were taken as 0.25 and 0.50, respectively, as per FAO recommendation. The *P-M* equation reduces to the form:

$$ET_0 = \frac{0.0864}{\lambda} . \frac{\Delta(R_n - G) + c_p \rho_a DPV / r_a}{\Delta + \gamma(1 + r_c / r_a)} \quad \text{.................................} (1)$$

where λ is the latent heat of vaporization ($MJkg^{-1}$); Δ the slope of the vapor pressure versus temperature curve (kPa $^0C^{-1}$); γ the psychrometric constant (kPa $^0C^{-1}$); R_n the net radiation (Wm^{-2}); G the soil heat flux (Wm^{-2}); c_p the specific heat of air (1013 Jkg^{-1} C^{-1}); ρ_a the atmospheric density (kgm^{-3}); DPV the vapour pressure deficit (kP_a); r_a the aerodynamic resistance (sm^{-1}); r_c the bulk canopy resistance (sm^{-1}); and the ratio $0.0864/\lambda$ was used to transform Wm^{-2} to mm per day. The practical limitation of P–M method for predicting the ET_0 at field level in Bangladesh is the lack of climatic data such as solar radiation/sunshine hour, wind speed, etc.

The water deficit for the dry months (Nov.–March) was calculated for crop planning interpretation. It was calculated from the equation given below:

$$\text{Deficit} = \text{PET} - R_{av.} \quad \text{...} (2)$$

where, PET is the potential evapotranspiration (taken as the same of ET_0), R_{av} is the average rainfall.

Results and Discussion

Climatic variables

The important climatic elements (mean monthly) of Mymensingh location are shown in Fig. 2. It is observed that the distribution of rainfall over the months of the year is quite uneven. About 70 % of the annual rainfall occurs during the months of June to September and 90 % during May to October. These wet months characterized by high humidity, average maximum temperature, higher photo-period but lower bright sunshine hour, and high wind speed. The rainfall at all locations are uneven, and erratic (not shown), having similar pattern.

Pattern of ET_0

The pattern of ET_0 values for all locations are pictured in Fig. 3. The pattern is almost similar, having a change in magnitude of highest and lowest values. The highest value of ET_0 correspond to higher temperature, sunshine hour, wind speed and lower humidity.

There is a linear relationship between solar radiation and dry matter production. As the solar radiation is not measured in many places, it can be gauged from potential evapotranspiration (PET). Cochrane and Jones (1979) considered the total potential evapotranspiration during the wet months as a measure of the total energy available for plant growth. Like many tropical countries, yield potential of a particular cultivar in Bangladesh is higher in dry season (January-May) than that of the wet season (July-October) due to availability of higher solar energy. It is clear from Fig. 3 that the ET_0 , which is the indirect estimation of solar energy, is higher during the dry period.

Crop planning

The long-term average of monthly rainfall along with mean monthly PET is depicted in Fig. 4. The period from May to October is moisture surplus period (rainfall>PET), and as a consequence, crops do'not face any moisture stress. The major Kharif-I and Kharif-II crops during April to October in different locations of the country is rice, and there is no shortage of water except occasional drought period when dry spell continued for long time affecting crop growth.

The duration from November to March, and in some instant upto April is deficit period (rainfall<PET). But from the viewpoint of availability of solar energy, this period is best suited for crop production (Hossain *et al.*, 2001). Management of water for crop growth during this period is important for the Agriculturists.

Based on the rainfall data, the minimum expected rainfall at 80 % level of probability (P80) during November to March (assured rainfall) was 56 to 140 mm (Table 1) and during November to February was 31 mm to 85 mm. Total deficit at P80 from November to March at different locations ranged from 47 mm to 115 mm, whilst the available water-storage capacity of 60 cm root zone soil are 45 mm, 60 mm, and 80 mm for sandy loam, silt loam, and clay loam soil, respectively (Michael, 1996).

Hargreaves (1975) reported that the attainment of actual evapotranspiration to potential evapotranspiration (AE : PET) value at 0.33 was sufficient for the growth of potato, maize etc. Sivakumar and Virmani (1979) gave the similar opinion for the growth of sorghum.

The cropping pattern of different regions of the country are based on rice. Immediately after harvesting the transplanted Aman rice at the end of October, farmers can grow a pulse, groundnut, or wheat crop utilizing residual soil-moisture. Satisfactory yield for lentil, groundnut, potato, mustard, chickpea, and wheat can be achieved only utilizing 65, 70, 100, 60, 65 and 100 mm water, respectively (Sarker *et al.*, 2000; BINA, 1998a; Hassan *et al.*, 2002; BINA, 1998b; Rahman and Islam, 1991). If the stored moisture from the previous season is utilized, it can provide satisfactory yield without irrigation. One or two irrigations with 3 to 5 cm depth depending on the availability of water will speed up the growth to give better yield.

To grow crop under rainfed condition, short duration and low-water demand crop varieties can be chosen. In addition, the areas where usually occurs excessive depletion of the groundwater (e.g. Rajshahi) (BINA, 2004) and problems like arsenic contamination has been started; the above mentioned dry-land crops may be produced instead of winter rice (*boro*) for a sustainable and environment-safe agricultural production.

Table 1. Rainfall and deficit amount during November to March at different locations

	Location					
	Mymensingh	Pabna	Rangpur	Rajshahi	Comilla	Khulna
Rainfall (at P80), mm	94	140	56	64	121	100
Total deficit (mm)	72	47.6	115.8	122.5	52	82.8

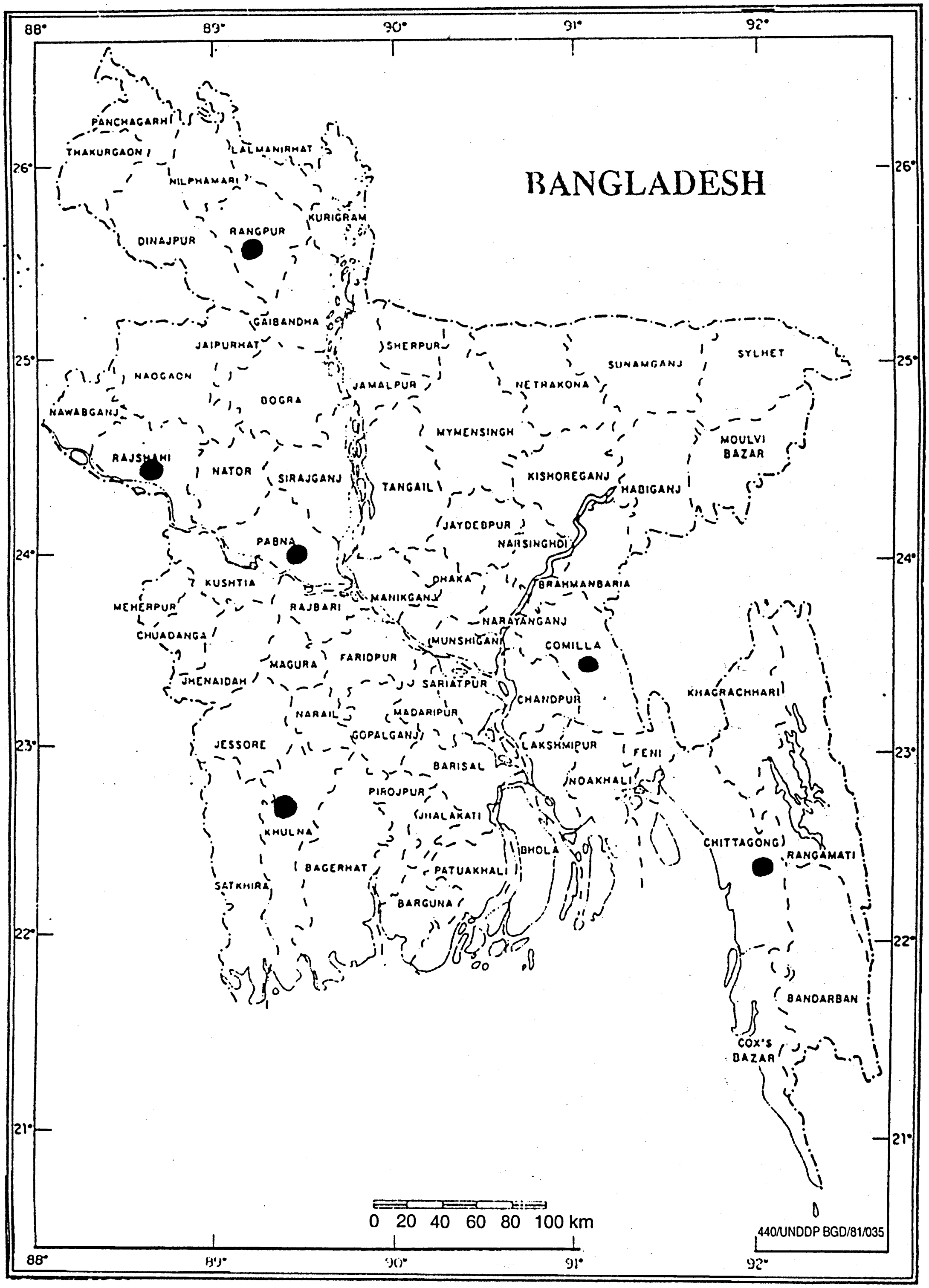

Fig. 1. Map of Bangladesh showing the position of selected meteorological stations

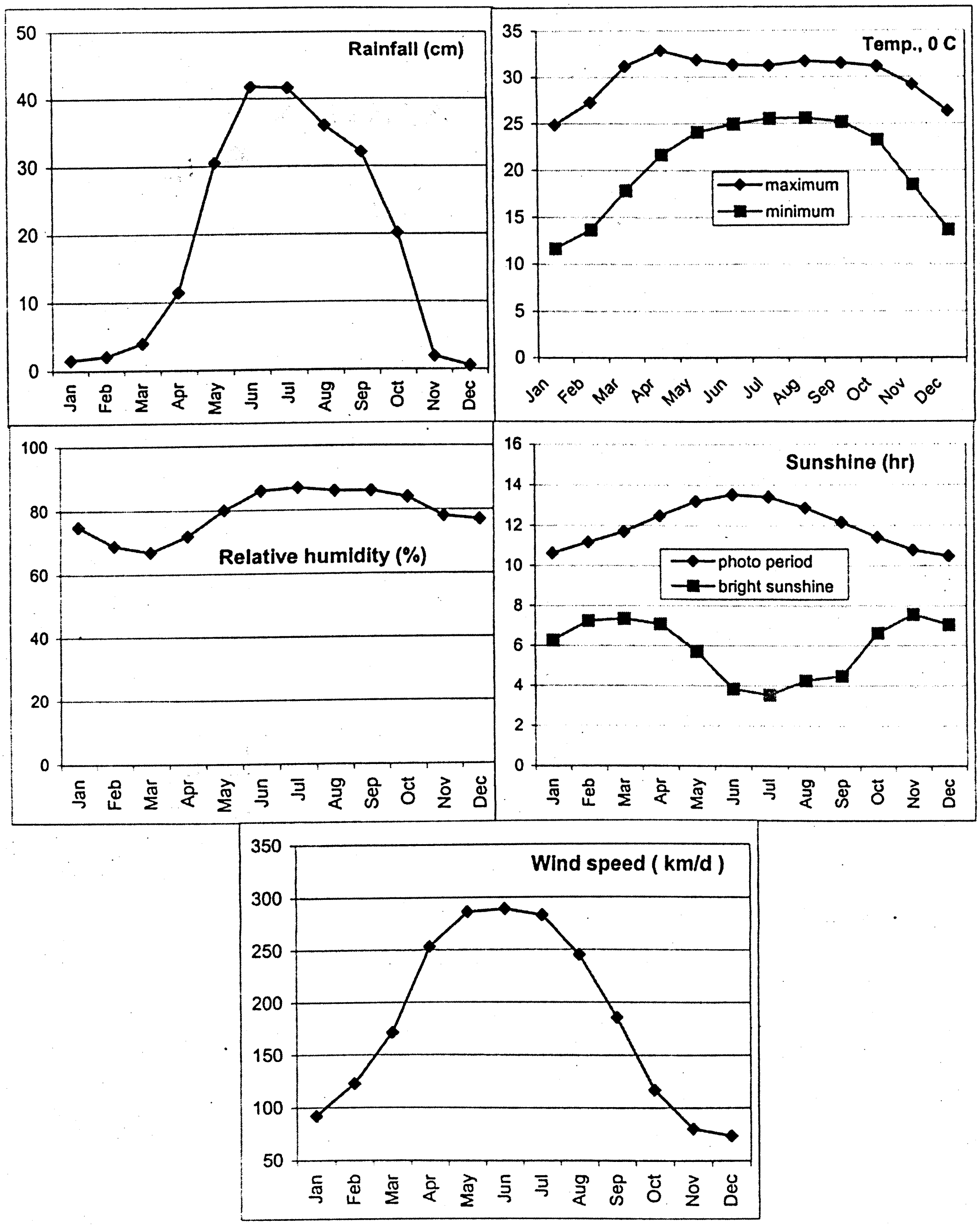

Fig. 2. Mean climatic variables throughout the year at Mymensingh

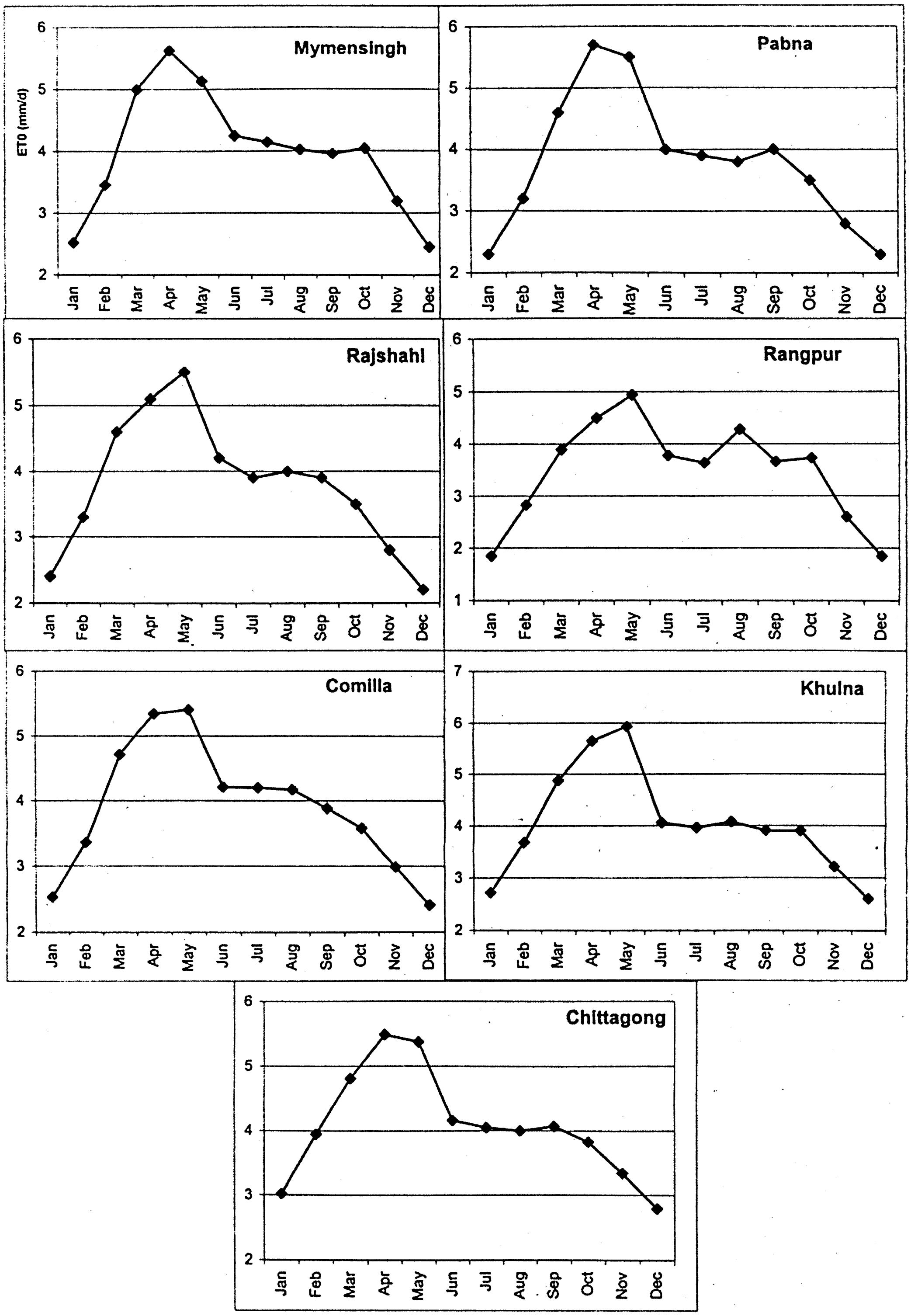

Fig. 3. Mean ET_0 throughout the year at different locations

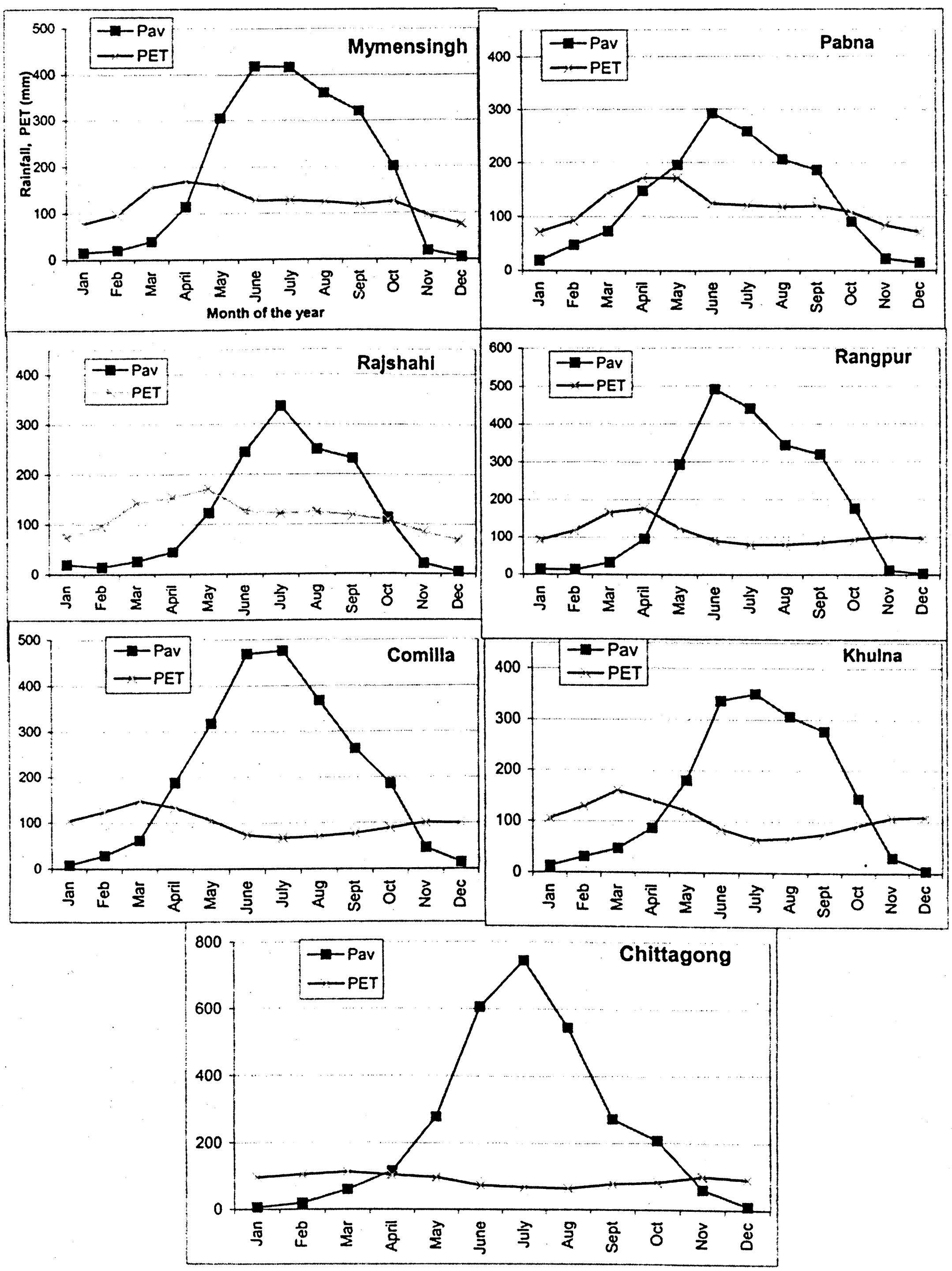

Fig. 4. Long-term average of monthly rainfall and potential evapotranspiration (PET) at different locations

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