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CHANGES OF REFERENCE EVAPOTRANSPIRATION (ET_0) IN RECENT DECADES OVER BANGLADESH

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ABSTRACT

The quantification of water balance is crucial in Bangladesh due to increasing demand of water for agricultural production. One way to estimate the water requirements is the determination of reference evapotranspiration (ET_0). The ET_0 values measured or calculated at different locations or in different seasons are comparable as they refer to the evapotranspiration from the same reference surface. The only factors that affect ET_0 are the climatic parameters. Any change in climatic parameters might lead to changes in ET_0 over a particular area. In this study, an attempt has been made to investigate the changes of ET_0 in the past several decades over Bangladesh under the changing climate. Daily observed data are collected from the Bangladesh Meteorological Department (BMD) for the 1971 to 2010 time period. ET_0 are analyzed using the FAO Penman-Monteith method which is recommended as the sole method for determining ET_0. A software called CROPWAT 8.0, developed by Water Resources Development and Management Service of Food and Agricultural Organization (FAO) has been used to calculate ET_0 in the study. Two historical time-slices each 20 years of length i.e. 1971-1990 as 1980s and 1991-2010 as 2000s are considered to investigate the change of ET_0 over Bangladesh. In the recent decades, the average evapotranspiration in Bangladesh has reduced from January to April. However, from July to December, ET shows slight increase in recent decades. Spatial Analysis has revealed that ET_0 has reduced more in the western part than in the eastern part of the country. The south eastern region of Bangladesh shows a notable decrease of ET_0 particularly in Meherpur District during *Kharif-I* cropping season.

Keywords: Agro-meteorology, Climate Change, Reference evapotranspiration

INTRODUCTION

According to Allen et al. (1998), reference evapotranspiration (ET_0) or sometime referred as reference evapotranspiration (ET_0), can be defined as the rate of evapotranspiration from a hypothetical reference crop with an assumed crop height of 0.12 m, a fixed surface resistance of 70 sm/1 and an albedo of 0.23. This parameter plays an important role in hydrology, watershed management and agriculture sectors. Estimation of ET_0 is essential for the irrigation scheduling, calculation of crop water requirements, design of irrigation and drainage structure as well as for the study relative to climate variability (Liang et al., 2010). As Bangladesh has agriculture based economy, this parameter exerts more importance in water management practice of the country.

ET_0 depends on several climatic parameters like air temperature, wind speed, relative humidity, and shortwave radiation etc. However, it is evident from recent report of IPCC (2007) that earth temperature has been continuously raising in recent decades, causing a change in total climatic system of the globe. As a consequence, all the dependent parameters of ET_0 also showed some differential changes in their variability and magnitudes. This provides a heterogeneous changing pattern of ET_0 all around the world. Such changes, eventually affects a number of vital sectors e.g. agriculture and food security, water resources and ecosystem, health and livelihood etc. both in global and regional scale. Thus, for the climate vulnerable country like Bangladesh, it is essential to understand the change of ET_0 for the proper management practice, effective planning and robust decision making in the agriculture and water sectors. Several studies have already been made regarding the regional changes of ET_0 under climate change (Chattopadhyay and Hulme, 1997; Gong et al., 2006; Goyal, 2004; Moonen et al., 2002; Shenbin et al., 2006; Wang et al., 2007; Xu et al., 2006; Youqi et al., 2008), but none of them are available over this region. Therefore, this study is conducted to identify the significant changes of ET_0 over Bangladesh in both spatial and temporal scale.

Estimation of ET_0 can be done in two ways, one is by meteorological data and another is by hydrologic models. The Penman–Monteith (PM) equation has emerged as the de-facto standard to calculate ET_0 with the help of meteorological data. This method provides values that are very consistent with actual crop water usage data worldwide as it has been demonstrated through many years of evaluations reported in the scientific literature. This method explicitly incorporates both physiological and aerodynamic parameters. Moreover, procedures have been developed for using this method even with limited climatic data. Therefore, this study calculates and compares ET_0 over Bangladesh under prevailing climate change condition. To estimate ET_0, daily meteorological data were collected from 36 stations over Bangladesh from 1971 to 2010. Changes of estimated ET_0 are determined by comparing results of the last 20 years with the previous 20 years.

METHODOLOGY

Bangladesh is tropical country with a high intensive annual rainfall. Other than rainfall and temperature data, meteorological variables like wind speed, solar radiation etc. are not available with continuous integrity in the existing global observed data sets. However, data from 34 stations maintained by the Bangladesh Meteorological department (BMD) are available that allowed to calculate ET_0 estimates over the country. In this study, six daily meteorological variables are collected from BMD including daily (1) minimum air temperature (Tmin, °C), (2) maximum air temperature (Tmax, °C), (3) relative humidity (Rh), (4) wind speed at 2 m (U_2, m/s), (5) bright sunshine hours (N, h/d) and (6) precipitation (P, mm/month). Mean monthly air temperature are calculated by taking the average of the maximum and minimum air temperature. After quality control, six stations are removed from the analysis as they have missing value greater than 20% and failed in the homogeneity test. Twenty eight out of these thirty four stations has long term quality controlled data sets dated back to the independency of country (at 1971). Data from all stations ranging from 1971 to 2010 have been used to compare the mean state of reference evapotranspiration over Bangladesh. Two periods of each 20 years of length (i.e. from 1971 to 1990 as 1980s and from 1991 to 2010 as 2000s) are considered to investigate the change of climate variables.

Daily ET_0 rates has been estimated according to the Penman–Monteith (PM) procedure and summed to monthly values. The Penman–Monteith approach is regarded as the most accurate method under all climates giving estimates that differ less than ±10% from the actual values (Allen et al., 1998). The PM method for calculating daily reference evapotranspiration is:

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma\frac{900}{T+273}u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \quad (1)$$

Where, ET_0 is the reference evapotranspiration (mm day^{-1}); R_n is the net radiation at the crop surface (MJm^{-2} day^{-1}); G is the soil heat flux density ($MJm^{-2}day^{-1}$); T is the mean daily air temperature at 2 m height (°C); u_2 is the wind speed at 2 m height (ms^{-1}); e_s is the saturation vapour pressure (kPa); e_a is the actual vapour pressure (kPa), Δ is the slope vapour pressure curve ($kPa°C^{-1}$) and γ is the psychrometric constant ($kPa°C^{-1}$).

With the collected climatic variables, the calculation of ET_0 has been done using a software known as 'CROPWAT'. 'CROPWAT' is a software developed by Joss Swennenhuis for the Water Resources

Development and Management Service of FAO and useful tool for determination of crop water requirements and irrigation requirements of a particular crop (Clarke et al., 2001). All calculation procedures of the software are based on the FAO guidelines and it can used to calculate references evapotranspiration or ET_0 using PM method. Using this software ET_0 has been estimated with 28 station data for the time period of 1971 to 2000. After calculation of daily ET_0 rate, monthly and climatic ET_0 has been determined to assess the potential changes of ET_0 in recent years. For the agricultural importance of ET_0 in Bangldesh, the assessment has been made for three cropping seasons, namely *Rabi*, *Kharif-I* and *Kharif-II*. *Kharif-I* season ranges from March to July, *Kharif-II* season ranges from July to October and Rabi season ranges from November to February.

RESULT AND DISCUSSION

To understand the change of climatic mean of ET_0, monthly evapotranspiration has been analyzed for 1980s and 2000s time period as shown in Figure 1. From the January to April, average evapotranspiration in Bangladesh reduces from the past decades (1980s) and highest reduction is observed during January is about 6%. But from July to December, ET_0 shows increasing trend in the recent decades (2000s). As, rainfall during November and December is very low compare to other months of the year, continuing increases of ET_0 during these months results irrigation water deficiency over the country which might hamper the production of cold loving *Rabi* crops like wheat, potato etc.

Spatial distribution of reference ET has made in the study for two so called historical time slices. Comparison has been made for different croping seasons of the country as shown in Figure 2 and Figure 3. In 1980s, ET_0 over the western part of the country varies from 4.5mm to 5.7mm per day, whereas the eastern part of the country experiences lesser rate of ET_0 during *Kharif-I* season. However, reference ET distribution shows less spatial variability ranging from 3.8 to 5 mm per day in 2000s. The south eastern region of Bangladesh shows a notable decrease of reference ET especially in Meherpur District. It can be suggested that reference ET has decreased during *Kharif I* season in recent climate. On the other hand, during *Kharif II* season, reference ET has shown more variability in the coastal areas of the country in 1980s and deceased at a rate of 0.2 to 0.3 mm per day in 2000s. But in the north western parts of the country, reference ET has been increased rapidly than any other parts of the country. On the other hand, during *Rabi* season, reference ET has not changed much around the country. Slight reduction of reference ET occurs in the western parts of the country.

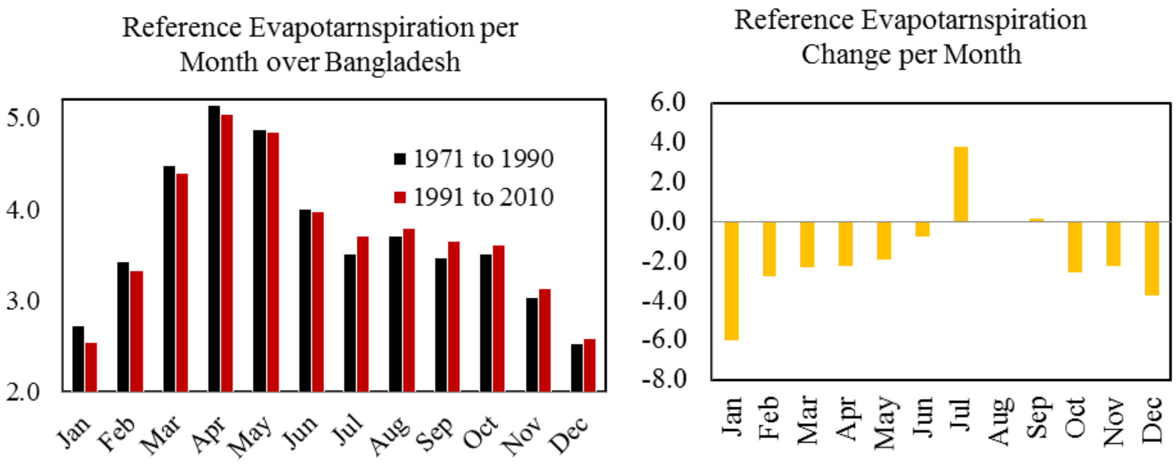

Figure 1: Monthly reference evapotarnspiration (left) and their changes (right) over Bangladesh during two histrocial time slices (1971-1990 & 1991-2010).

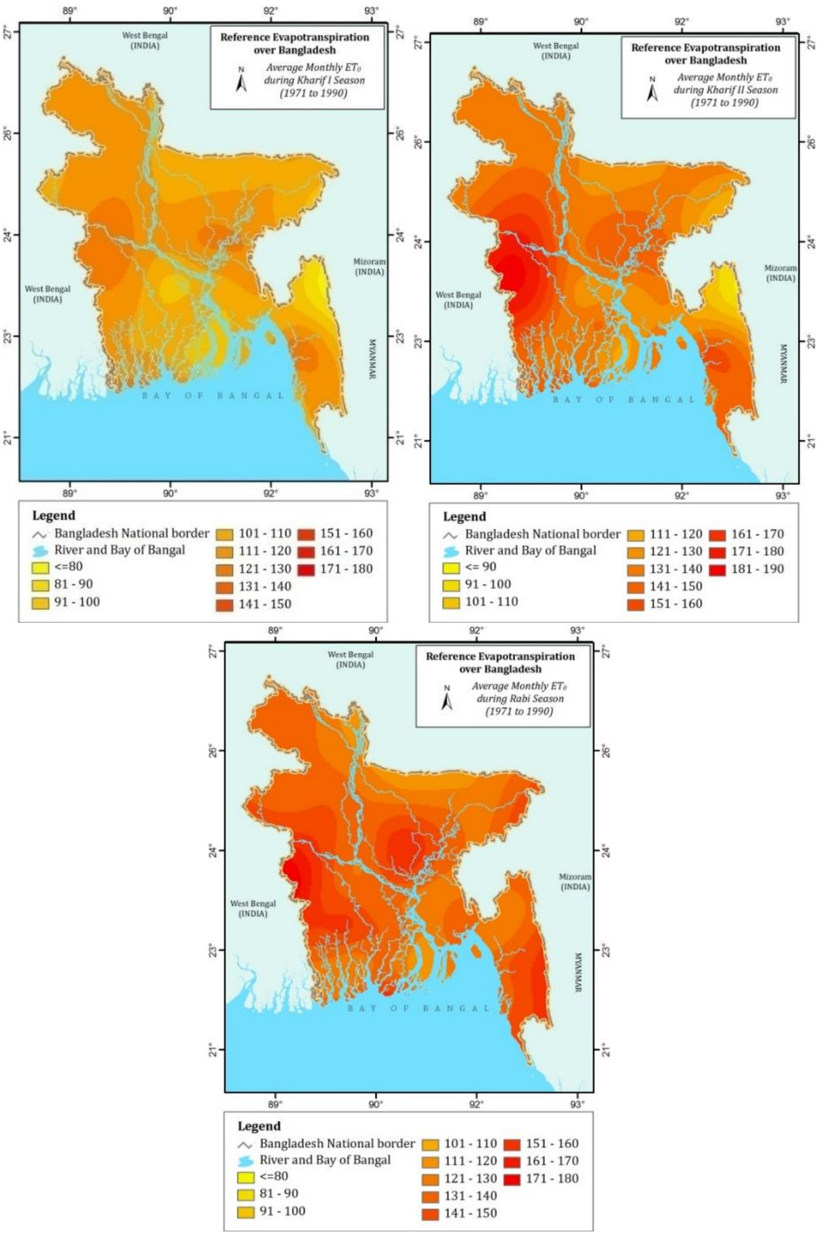

Figure 2: Reference evapotranspiration over Bangladesh at *Kharif I*, *Kharif II* and *Rabi* season (left to right) during 1971 to 1990.

CONCLUSION

Reference evapotranspiration (ET_0) has been estimated over Bangladesh in both monthly and seasonal time scales during two historic periods (1971-1990 and 1991-2010). Study reveals that ET_0 have decreased from January to April and increased from July to December. Decrease of evapotranspiration during November and December might hamper the crop production. Condition will be much aggravated for the cold loving crops as the night time temperature will increase in the future (Hasan et al., 2013).

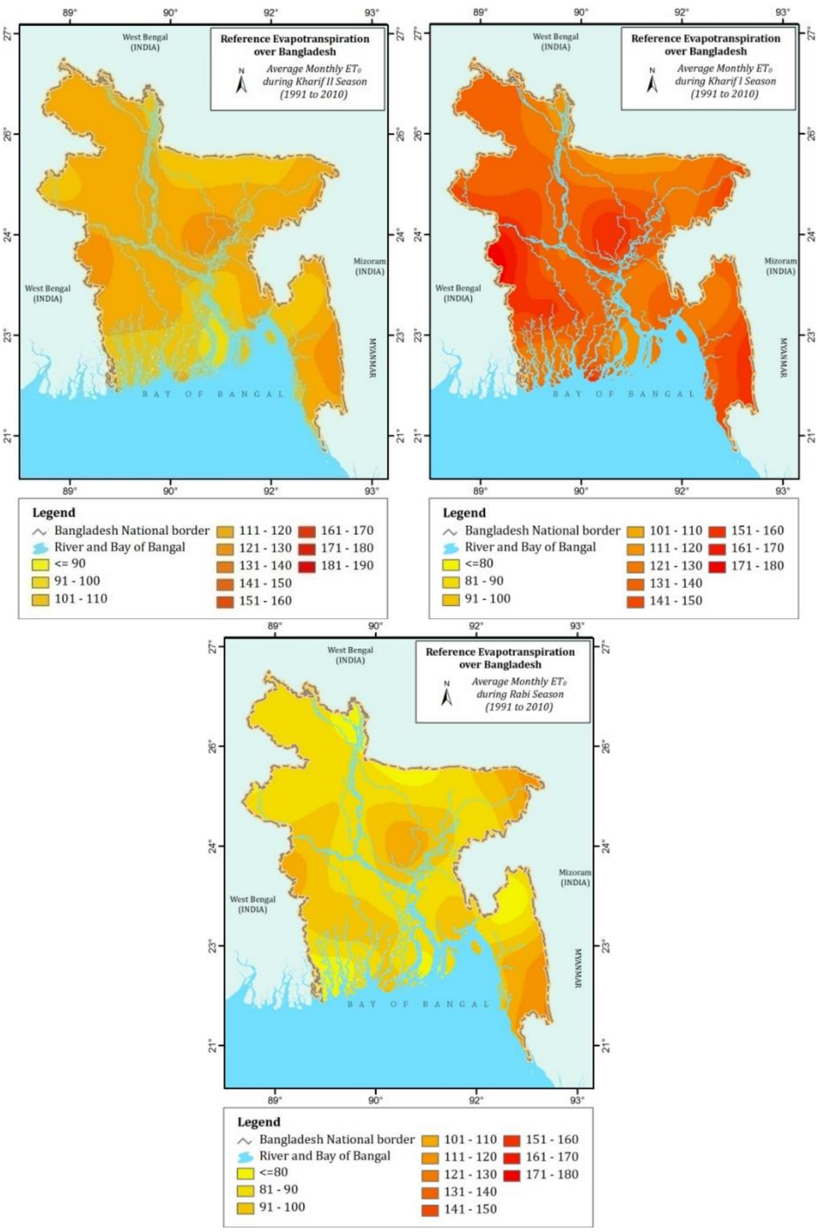

Figure 3: Reference evapotranspiration over Bangladesh during *Kharif I*, *Kharif II* and *Rabi* seasons (left to right) in 2000s.

Kharif-I seasons observes a decreasing trend of mean ET_0 over Bangladesh. During *Khari-II* season, ET_0 increases rapidly in the north western parts of the country. During the *Rabi* season, ET_0 decreases at a uniform rate in all over the country. Seasonal water requirements of any particular crop can be determined by multiplying crop coefficient of that crop. This study reveals spatial and temporal changes of ET_0 over Bangladesh which can help to improve the future water management practices of the country. This information can also be useful for the improvement of agro-climatic zoning of Bangladesh.

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