

Impact of climate change on crop water demand and its implication on water resources planning : Bangladesh perspective

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ABSTRACT

An investigation was made on the response of evapotranspiration (representation of crop water demand) due to possible changes in climatic parameters at three locations of Bangladesh. The results suggest an increase of 11 to 15 % of total ET demand with an increase in maximum temperature (in isolation) by 20 %. Increase of 10% in temperature alone with 10 % decrease in bright sunshine hour (SH) and wind speed (WS) could result even in marginal increase in total ET (3.1%). A 10% increase in temperature coupled with 10 % increase in SH, WS, and 15 % decrease in relative humidity could result in 18.5 % increase in annual ET. Any change in evapotranspiration will be likely to have a profound effect on agriculture and water resource planning. It is the time for planners/users to think in terms of expected change in water requirement due to global climate change while planning for development of future water resources. A wide spectrum climate change scenario is discussed in the paper as guideline for future development and planning of water resources.

Keywords : Climate change, evapotranspiration, crop water demand, water resource planning, Bangladesh

The perturbation of atmospheric process by anthropogenic activities of man have been a great concern now a days, which include possible climatic effects due to solar or terrestrial infrared radiation fields, possible changes of cloud processes, global warming and environmental effects (Ashenden and Bell, 1989). Gradual build up of greenhouse gases is bringing about changes in global climate (Droogers, 2004; IPCC, 2001; Marchand *et al.*, 1988; Gleick, 1987). Since the inception of this century,

earth's surface appears to have been warmed by about 0.5 degree centigrade and the pace of warming is likely to be faster in future. The most up to date predictions are for an increase in global temperature of 2 - 6 °C by the end of the century (Bind and Howden, 2004).

Irrigation water demands are particularly sensitive to changes in precipitation and temperature (Frederick and Major, 1997). Global warming may alter

not only temperature, but also cloudiness, windiness and humidity as well. All these factors determine the atmospheric demand for water vapour or its drying power, hence the crop water demand.

Bangladesh, a densely populated country in the world (national average is 910 person per square kilometer) is facing an acute shortage of fresh water. Although the country receives plenty of rainwater, it is seasonal, concentrated over a few months (May to August) and leaving the rest of the months dry. Major source of irrigation water for dry-season cropping is ground-water. Vertical (increased cropping intensities) and horizontal (cultivation of crops on new lands) expansion of irrigated agriculture to feed ever-increasing population have contributed (and may continue) to affect the availability of good quality irrigation water (such as exemplified by arsenic contamination). Any change in evapotranspiration or crop water demand will be likely to have a profound effect on agriculture and water resource planning and management. In this study, an investigation was made on the likely change in evapotranspiration demand taking into account a wide spectrum scenario of climate change, taking the climatic data of three agro-ecological zones of Bangladesh.

MATERIALS AND METHODS

Study area

Data of three different weather stations located at different representative

agro-ecological zones of the country were selected for study. The stations were namely: Mymensingh (24°43'N, 90°26'E, and 19 m amsl), Rangpur (25°45'N, 89°15'E, and 34 m amsl), and Rajshahi (24°24'N, 88°48'E and 34 m amsl). Data of the climatic variables were collected from Bangladesh Meteorological Department. Monthly average of long-term meteorological parameters have been used as reference data for study. Monthly average climatic variables of the study areas are given in Fig. 1.

The potential (or reference) evapotranspiration has been studied by varying individual meteorological parameters (in isolation) within a range, as described in Table 1, while keeping other parameters constant. ET was also studied by varying multiple parameters in combination. The reference evapotranspiration (ET_0) values were calculated using FAO CROPWAT model, windows version 4.2 (FAO, 1995).

RESULTS AND DISCUSSION

The relative changes in annual ET due to relative change in climatic parameters are presented in Table 2 for individual climatic parameters. In response to the change in temperature by $\pm 20\%$, ET varied between -11.6 to $+15.2\%$ in comparison to increased temperature. Change in minimum temperature has a little effect on annual ET. The ET showed an increasing trend with the decrease in humidity and vice versa.

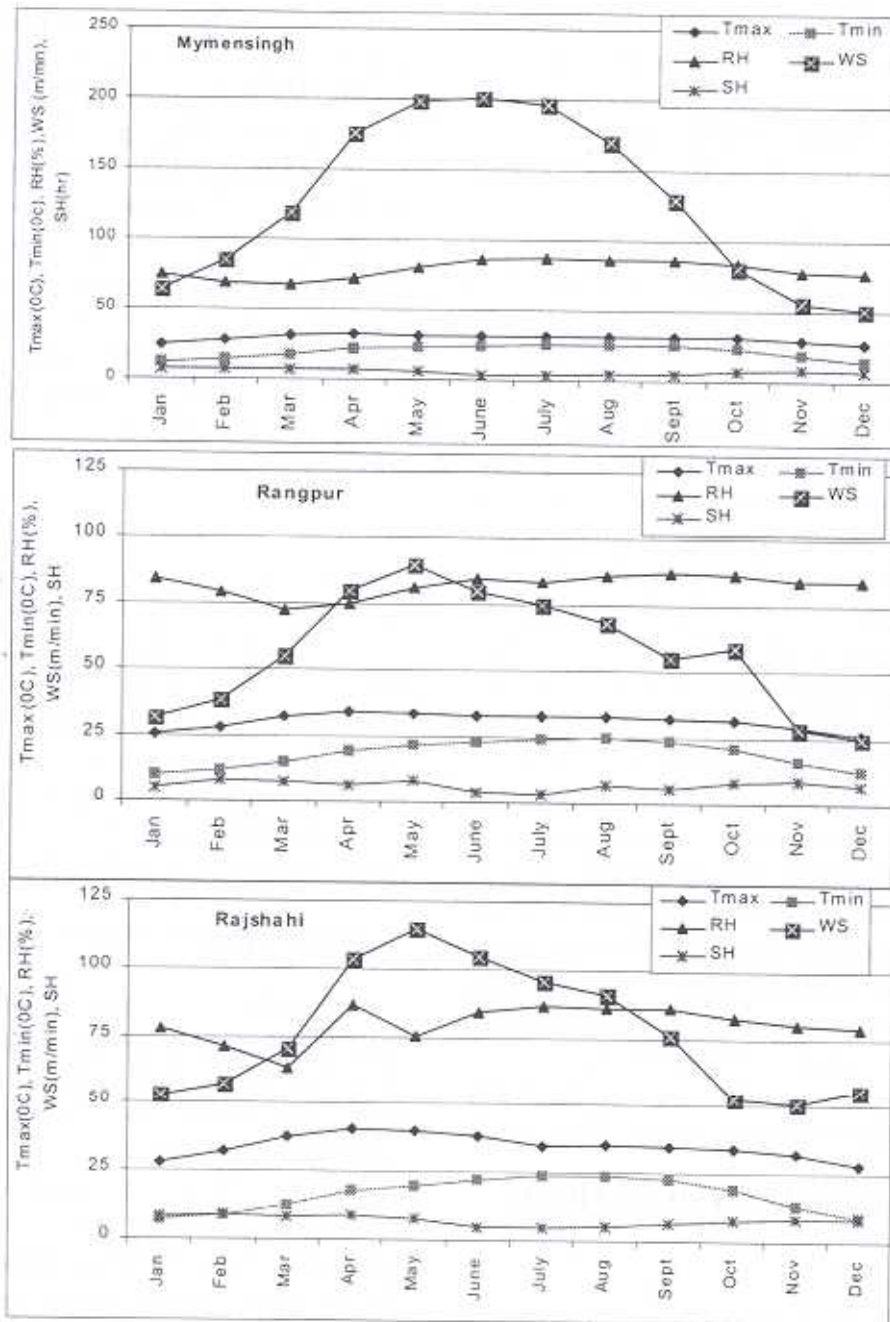


Fig. 1 : Monthly average climatic pattern of the studied locations

Table 1 : Variability of the climatic parameters studied

Sr. No.	Climatic variables*	Variations
1	Maximum temperature (T_{max}), $^{\circ}C$	$\pm 5\%$, $\pm 10\%$, $\pm 20\%$
2	Minimum temperature (T_{min}), $^{\circ}C$	$\pm 5\%$, $\pm 10\%$, $\pm 20\%$
3	Average relative humidity (RH), %	$\pm 5\%$, $\pm 10\%$, $\pm 15\%$
4	Wind speed (WS), km/d	$\pm 5\%$, $\pm 10\%$, $\pm 20\%$
5	Bright sunshine hour (SH)	$\pm 5\%$, $\pm 10\%$, $\pm 20\%$

Table 2 : Percent change in ET from base due to percent change in climatic parameters

Location	Parameter	% change in ET from base					
		-20 %	-10 %	-5 %	+ 5 %	+ 10 %	+20 % *
Mymen-singh	T_{max} ($^{\circ}C$)	-12.3	-6.87	-3.58	4.06	7.29	11.25
	T_{min} ($^{\circ}C$)	-0.38	-0.15	-0.15	0.31	0.78	2.66
	RH (%)	10.3	6.4	3.28	-1.87	-6.56	-8.35
	WS (Km/d)	-2.65	-1.4	-0.32	0.79	1.67	2.49
	SH	-6.36	-3.1	-1.52	1.56	3.12	6.24
Rangpur	T_{max} ($^{\circ}C$)	-11.6	-6.4	-3.3	3.5	6.9	14.7
	T_{min} ($^{\circ}C$)	-0.7	-0.5	-0.4	0.4	0.9	2.2
	RH (%)	4.7	3.1	2.0	-2.2	-4.4	-6.2
	WS (Km/d)	-1.8	-1.1	-0.5	0.4	0.9	1.6
	SH	-6.4	-3.5	-1.8	1.6	3.3	6.6
Rajshahi	T_{max} ($^{\circ}C$)	-12.0	-6.5	-3.3	3.5	7.3	15.2
	T_{min} ($^{\circ}C$)	-1.5	-1.0	-0.6	0.6	1.3	3.3
	RH (%)	6.8	3.0	1.6	-1.7	-3.3	-5.1
	WS (Km/d)	-2.2	-1.0	-0.6	0.4	1.0	2.0
	SH	-6.5	-3.2	-2.2	2.0	4.1	7.5

* For humidity, it was considered 15% (as the value at 20 % becomes unrealistic (>100%) in some cases)

Wind speed and bright sunshine hours affect ET in similar fashion, with a little higher magnitude than that of bright sunshine hours. Increasing bright sunshine hours and wind speed by 20 %, increased ET by about 8 and 3 %, respectively, and vice versa.

Table 3 presents a scenario of 10% change in temperature with all probable changes of wind speed, bright sunshine hours and humidity at three locations. At Mymensingh, the ET varied from a marginal increase of 0.2 % (- 10 % SH, along with

Table 3 : Estimated total evapotranspiration demand in response to change in temperature by 10 % (both T_{max} and T_{min}) in combination with change in other climatic parameters

Case No.	% change in climatic parameter				Mymensingh		Rangpur		Rajshahi	
	T	SH	WS	RH	ET (mm)	% change	ET (mm)	% change	ET (mm)	% change
1	0	0	0	0	1335.6	-	1265.1	-	1381.5	-
2	+10	+10	0	0	1416.7	+6.1	1414.9	+11.8	1557.8	+12.8
3	+10	-10	0	0	1338.2	+0.2	1320.4	+4.4	1439.6	+4.2
4	-10	+10	0	0	1268.9	-5.0	1212.0	-4.2	1323.5	-4.2
5	-10	-10	0	0	1191.7	-10.8	1152.1	-8.9	1227.4	-11.2
6	+10	+10	+10	0	1512.7	+13.3	1426.4	+12.8	1579.8	+14.4
7	+10	+10	-10	0	1473.2	+10.3	1343.4	+6.2	1539.8	+11.5
8	+10	-10	-10	0	1377.2	+3.1	1311.2	+3.6	1421.6	+2.9
9	+10	-10	+10	0	1418.9	+6.2	1334.1	+5.5	1463.6	+5.9
10	+10	+10	+10	+15	1421.1	+6.4	1394.2	+10.2	1435.5	+3.9
11	+10	+10	+10	-15	1582.9	+18.5	1539.2	+21.7	1603.7	+16.1
12	-10	-10	+10	+15	1112.7	-16.7	1101.5	-12.9	1177.4	-14.8
13	-10	-10	-10	+15	1104.3	-17.3	1113.0	-12.0	1167.3	-15.5
14	-10	-10	-10	-15	1268.9	-5.0	1221.1	-3.5	1328.7	-3.8

10% increase in temperature) to a maximum of 18.5 % (+ 10% SH, + 10% WS, - 15 % RH, along with 10% increase in temperature). Increase in temperature by 10 % while decreasing other parameters (SH, WS) also results in marginal increase in total ET (3.1%). Decrease in temperature, SH, and WS by 10 % and an increase in RH by 15 %, could result in 17.3 % decrease in ET. For other two locations, the variation in ET showed similar pattern with minor change in magnitude.

An enormous amount of water is required to produce food (about 2500 – 3500 kg water per kg rice). In terms of water consumption, agricultural sector is the main water consumer in Bangladesh. Any change in crop water demand will be likely to have a profound effect on agriculture and water

resource planning. The present study provides an idea about the likely change in crop water demand at three locations, taking into account a wide spectrum scenario of climate changes. Changes in precipitation and stomatal resistance of crop to increased CO_2 are not considered in this study. Although the results presented in the study are estimates, this may be useful in planning, designing and operating irrigation system and crop planning in future. Long-term changes in evapotranspiration demand can have profound implications. Even small 5% increase in temperature from base data could result in an increase in ET by 43 to 54 mm (Table 2). The increased ET demand due to climate change can put pressure on existing overstressed water resources of Bangladesh.

CONCLUSION

It is evident from the study that any change in climate will have an impact on crop water demand, and therefore on agriculture and water resources planning in the area. The increased demand due to climate change can put tremendous pressure on existing overstressed water resources in many parts of Bangladesh. Increasing demand in water requires careful planning of crop (specially in diversified crop planning program) and future water resource development. More emphasis is needed to develop crop varieties requiring less water, changing cropping pattern including low water demand crop, to develop low-cost technologies for reducing water losses in the field specially in conveyance system, and conservation of rain-water.

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