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A Case Study on Sensitivities of Crop Water Use to Climate Changes

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1. INTRODUCTION

The climatic, physiologic and soil-physical factors which affect crop water use are analyzed. Direct and indirect pathways in which the green-house warming or climate change carries on its influence are drawn out. By using an improved method based on Penman's formula, the present crop water demand is calculated as the base case of no climate change, in Hanchuan County, China. Then sensitivities to various scenarios are simulated and analyzed by changing single or combined factors within their reasonable scopes.

2. METHOD

Climate changes bring affection in many ways as shown in Figure 1. Here only the main or direct effects are studied.

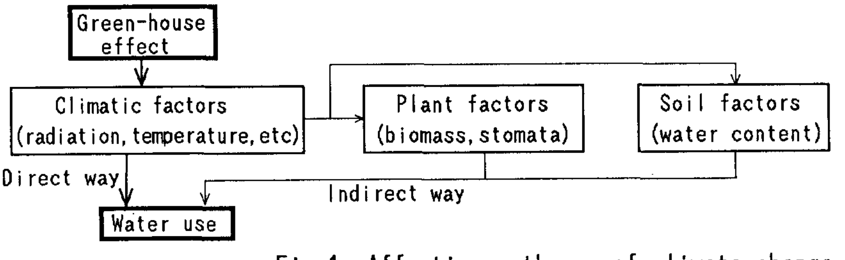


Fig.1 Affecting pathways of climate change

The formula for crop water use (ET) is frequently expressed as[1]

$$ET = k_c \cdot ET_0 \qquad (1)$$

where ET_0 is the reference evapotranspiration under standardized vegetation and water supply condition, and k_c is the synthetic crop coefficient determined with experiment on water use. An improved Penman's formula for ET_0 is set up as follows:

$$ET_0 = \frac{\Delta}{\Delta+\gamma}R_n + \frac{\gamma}{\Delta+\gamma}E_a \qquad (2)$$

$$E_a = 0.26(1.0+0.54u)(e_a-e_d) \qquad (3)$$

$$\frac{\Delta}{\Delta+\gamma} = 0.439+0.01124T \qquad (4)$$

$$\frac{\gamma}{\Delta+\gamma} = 0.5495-0.01119T \qquad (5)$$

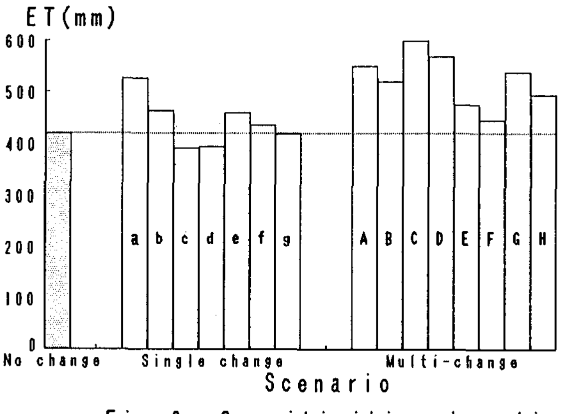
$$e_a = (3.817+0.014T)e^{0.0775T} \qquad (6)$$

where R_n—net radiation(mm/d), E_a—air drying capacity(mm/d), Δ—slope of relationship curve of saturation vapor and temperature, γ—psychrometric constant, e_a—saturated vapor pressure(mbar), e_d—actual vapor pressure(mbar), u—wind speed at 2 meter height(m/s), T—air temperature(^{0}C). And T, R_n, e_d and u represent the main four climatic factors of interest.

3. RESULT AND DISCUSSION

A rice farmland located at the Hanchuan County, Hubei Province of China is selected as the field case. Two kind of rices(I and II), with respective k_c values 1.2 and 1.27, are used for validating above method. Calculated life-time(some 90 days in May through August) water uses are 419.2 mm and 612.9 mm, very close to the observed 422.4 mm and 624.4 mm (percentage errors being 0.8% and 1.8% respectively).

According to research-of-art[2], under doubled green-house gases concentration, possible scope of climate change is reasonably taken as: temperature T +3^{0}C (against the annual average 15.0^{0}C and April-September average 25.0^{0}C); net radiation R_n ±10%; vapor pressure e_a ±10%; and windspeed u ±20%. Then sensitivities to single climatic factor and to multiple climatic factors are evaluated, by running the algorism under new scenarios and comparing resulted water resumption with the base case (Figure 2). Water use ET is most sensitive to temperature; an increase of 3^{0}C rises ET by 26%. ET is least sensitive to windspeed; a fluctuation of ±20% brings about only -2%——4% response in ET. The sensitivities of net radiation and humidity fall between those two factors. Among the eight scenarios for multi-factors change, the largest ET increase of 43-46% is caused by a combination of strengthened T, R_n and u and reduced e_d, and the very opposite combination produces the smallest ET change of 4-6%. Whatever scenario is considered, temperature always plays an important role.



SCENARIOS		T(°C)	R_n(%)	e_a(%)	u(%)
	a	+3			
	b		+10		
	c		-10		
	d			+10	
	e			-10	
	f				+20
	g				-20
	A	+3	+10	+10	+20
	B	+3	+10	+10	-20
	C	+3	+10	-10	+20
	D	+3	+10	-10	-20
	E	+3	-10	+10	+20
	F	+3	-10	+10	-20
	G	+3	-10	-10	+20
	H	+3	-10	-10	-20

Fig.2 Sensitivities to climate changes

It is pointed out that a true prediction on water use's variation could only be given by using output of GCM or meso-scale climatic models and by including more detailed mechanisms of water use. Nevertheless, the results presented above might show something about effects of climate changes.

References

[1] Doorenbus, J. and W. O. Pruitt, Guidelines for predicting crop water requirements, Irrigation and Drainage Paper, FAO, 1977.

[2] Waggoner, P. E., Climate change and U.S. water resources, John Willey & Sons Inc.,1990.