Implementing a Computable General Equilibium (CGE) Model under the BioEarth Framework

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INTRODUCTION

➢ Incorporating economic decision making into the BioEarth framework can be achieved by a Computable General Equilibrium (CGE) Model.

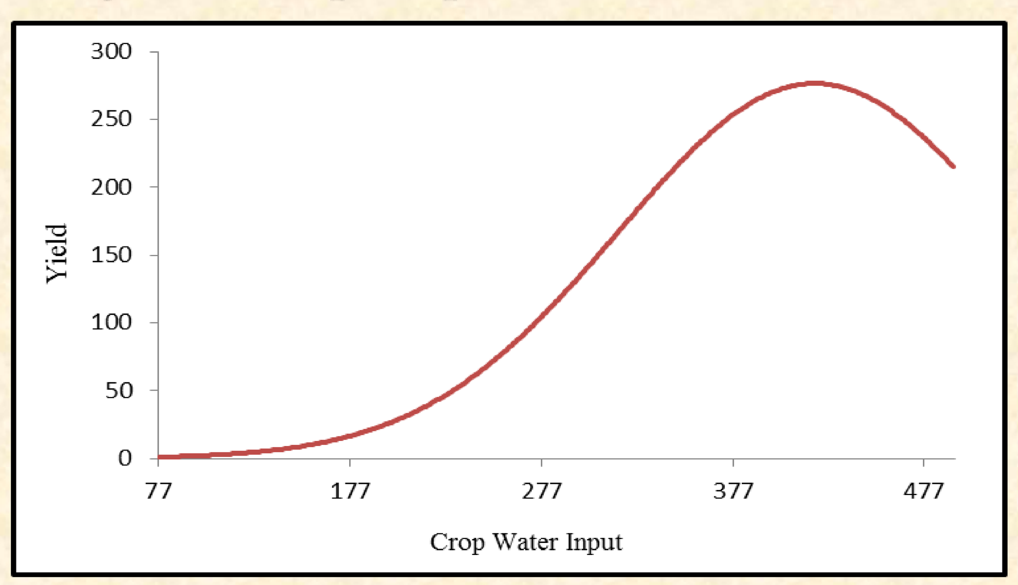
➢ A CGE model is a simulation that combines the abstract general equilibrium structure formalized by Arrow and Debreu with realistic economic data to solve numerically for the levels of supply, demand and price that support equilibrium across a specified set of markets (Wing, 2004).

➢Developing the BioEarth CGE model involves the **integration of VIC-CropSyst hydrology model outputs in the economic optimization model** as shown in Figure 1.

CROP RESPONSE FUNCTIONS

➢ Crop Response functions illustrate the relationship between crop water input variables and the crop yield. For example, the figure below shows the crop response function for Corn. It shows that as greater units of crop water input are applied , the marginal contribution to yield decreases beyond a certain level.

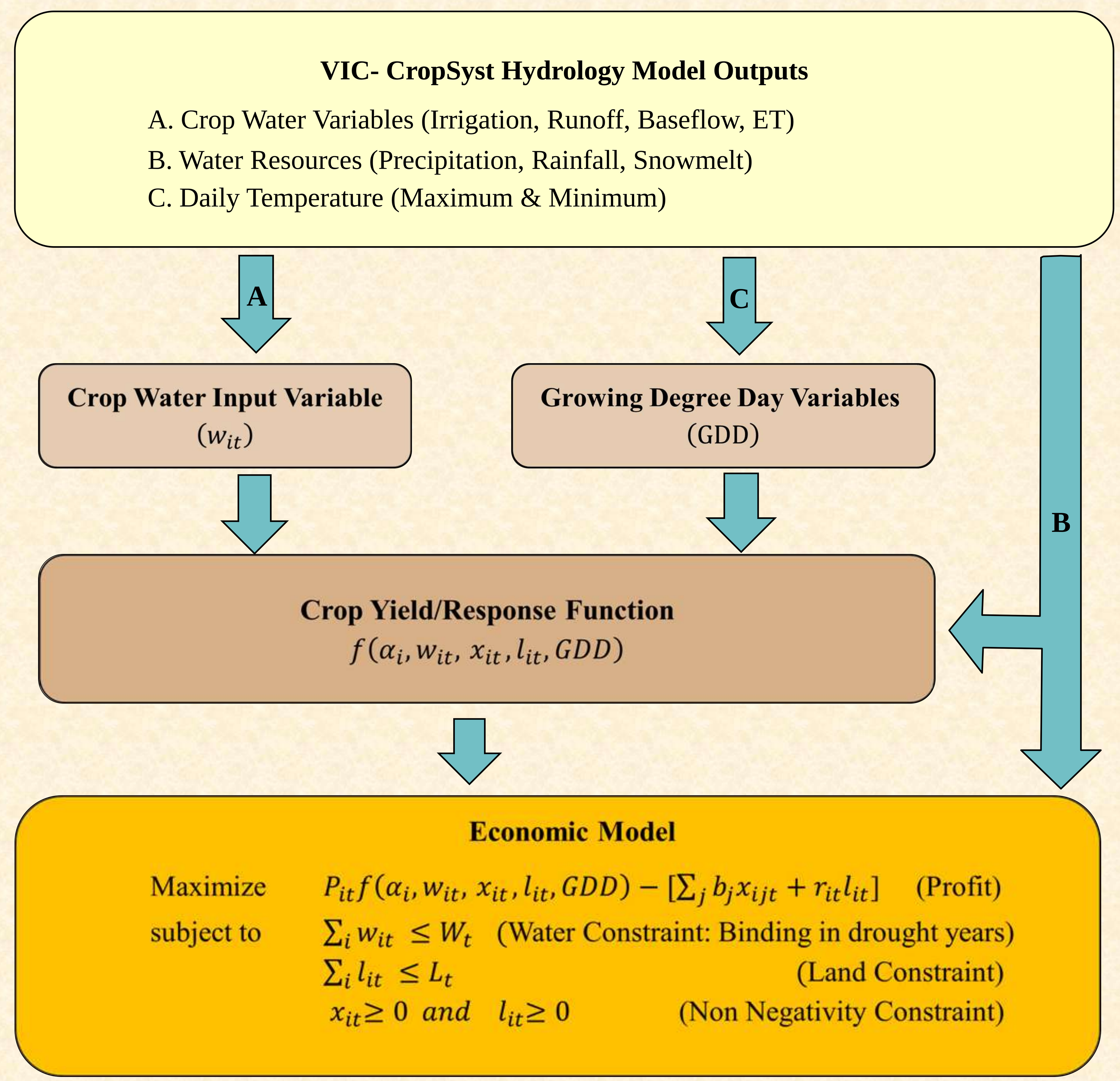
Figure 2: Crop Response Function for Corn



➢Apart from water input variables, crop response functions are also determined by:

- ❖ Acreage devoted to production of crop i in year t : l_{it}
- ❖ Other agricultural inputs used (fertilizer, pesticides, etc.): x_{ijt}
- ❖ Temperature as measured by Growing Degree Day interval variables: **GDD**
- ❖ Crop-specific parameters that characterize the physiological aspects of the crop's yield production : α_i

Figure 1: Developing the CGE Model



QUANTIFYING CROP WATER INPUT

➢ Under the CGE model, crop water input for crop i in year t is defined as: $w_{it} = \sum_{T=1}^{12} \delta_{iT} I_{iT}$ where δ_{iT} refers to weights based on crop growth stages. These are used to incorporate variability in crop water requirement during the growing season. Moreover, T= 1,2,3, … 12 denotes the months of the year t.

➢ $I_{iT} = Irrigation_{iT} + Rainfall_{iT} + Snowmelt_{iT} - Runoff_{iT} - Baseflow_{iT}$

GROWING DEGREE DAYS (GDD) INTERVAL VARIABLES

➢ According to Schlenker & Roberts (2009), there exists a non-linear relationship between temperature and crop yield., i.e., yield first increases and then later decreases in temperature. To capture this relationship we constructed GDD interval variables: $GDD"\gamma"_{it} = \sum_{n=1}^{365} GDD"\gamma"_{in}$ where $GDD"\gamma"_{in} = \begin{cases} 1 \text{ if } d_{\gamma 1} \le max.daily\ temp. < d_{\gamma 2} \\ 0 \text{ if } \quad max\ daily\ temp < d_{\gamma 1} \end{cases}$

➢ $\gamma = 1,2,..,8$ indexes the temperature intervals created by temperatures (in degree Celsius) $d_{\gamma 1} = (0,10,15,..,40)$ and $d_{\gamma 2} = (10,15,20,..,45)$. Please note that n = 1,2,…365 refers to days of the year t.

RESULTS

➢ In order to implement the CGE model we first determine the crop response functions (specifically the α_i's) by fitting the following regression equation to the VIC-CropSyst data and the constructed GDD and Crop water input variables. These results for the corn crop are as given below:

	Estimate	Std. Error	t value	Pr(>|t|)
Intercept	-46.37*	19.95	-2.32	0.03
w_{it}	0.0174***	0.00	8.99	0.00
Squared w_{it}	-0.00002075***	0.00	-5.09	0.00
GDD1	0.1219*	0.05	2.22	0.03
GDD2	0.1234*	0.05	2.27	0.03
GDD3	0.1191*	0.05	2.21	0.04
GDD4	0.1259*	0.06	2.28	0.03
GDD5	0.1308*	0.06	2.38	0.02
GDD6	0.1260*	0.05	2.32	0.03
GDD7	0.1484*	0.06	2.64	0.01
CO2	-0.0003	0.00	-0.77	0.45

➢We observe that all variables ,except for CO2 (Carbon Dioxide Pathway) are significant either at the 0.05 or 0.1 level (denoted by *** & *, respectively).

➢Moreover, the estimates for the crop water input variables satisfies the theoretical expectation for a concave crop response curve.

➢The GDD interval variables show that an additional day with the maximum daily temperature between 10 to 40 degree Celsius (GDD1 to GDD7) has a positive impact on crop yield. We believe that this finding merits further study.

NEXT STEPS

➢ Incorporate relevant crop and input prices (P_{it}, r_{it} & b_j) to solve the economic maximization problem.

➢ Expand CGE model to more crops and grid cells in the Columbia River Basin.

➢Explore developing linkages between the CGE model and the Agent Based Model (ABM).

REFERENCES

➢ Schlenker, Wolfram, and Michael J. Roberts. "Nonlinear temperature effects indicate severe damages to US crop yields under climate change." *Proceedings of the National Academy of Sciences* 106.37 (2009): 15594-15598.

➢ Wing, Ian Sue. "Computable general equilibrium models and their use in economy-wide policy analysis." *Technical Note, Joint Program on the Science and Policy of Global Change, MIT* (2004).