ARE WE AT A WATERSHED?
AN INTEGRATED ASSESSMENT MODEL FOR ITALY

Tiziano Distefano - U. of Florence, Italy.
Raphael Porchelot - U. of Florence, Italy.
Benedetto Rocchi - U. of Florence, Italy.
Gino Sturla - U. Diego Portales, Chile.
Mauro Viccaro – U. of Basilicata, Italy

31st International Input-Output Association Conference, Malé, Maldives.

Contents

I. Objetives

Objetives

1. Extend the EUROGREEN model with a hydrological module addressing blue and grey water demand and supply.
2. Integrate a dynamic IRIO model to explore climate and growth scenarios and assess economy–water feedbacks.
3. Develop and project and water exploitation index to evaluate water stress.

II. Methodology

The model

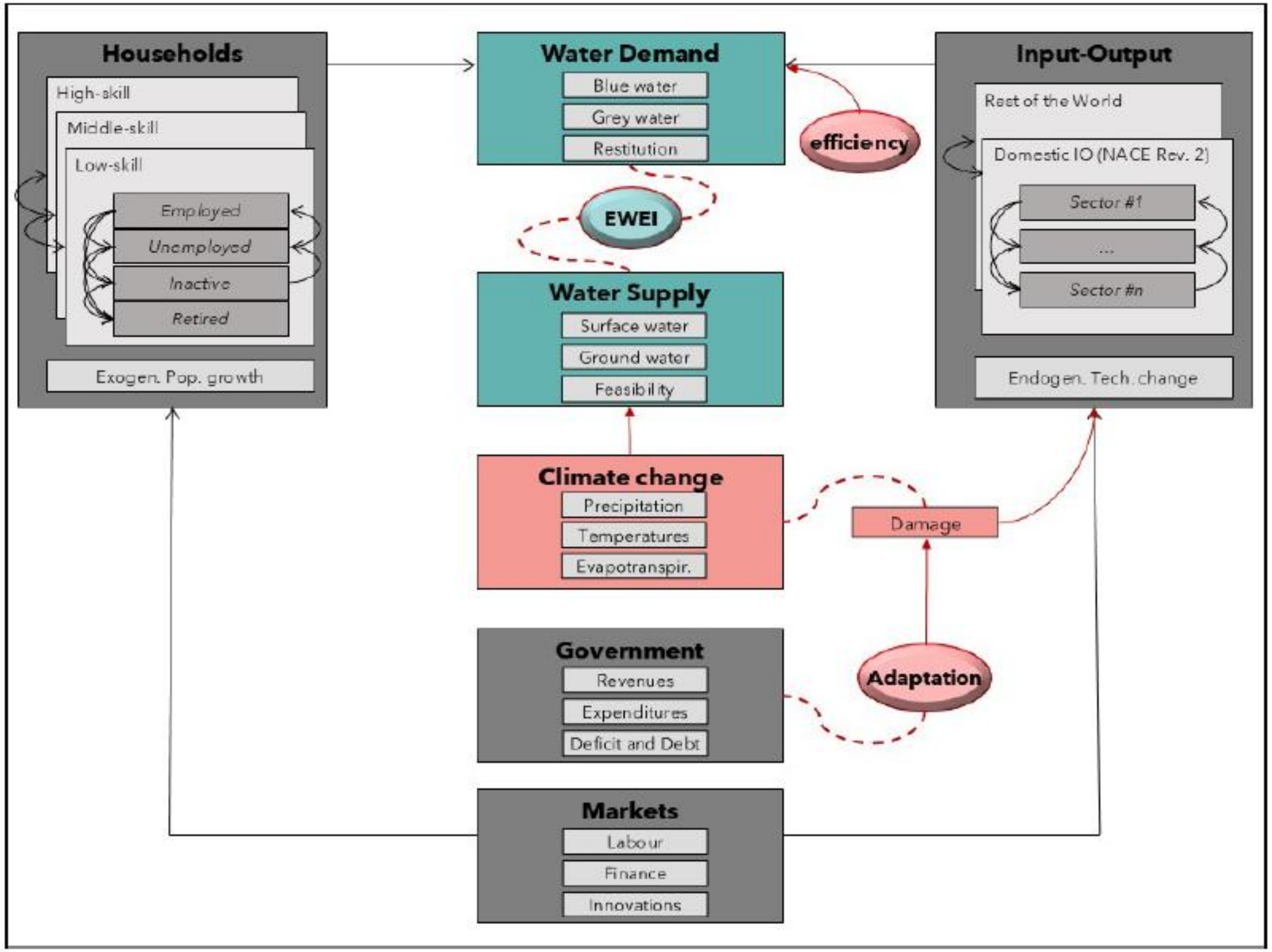


Figure 1: Macroview. The figure shows the key variables and connections of the current extended version of the EUROGREEN model (D'Alessandro et al. 2020a). by including the hydrological module and the impact of climate change (RCP 6.0) on water resources and economic activities.

Water module – Agricultural demand

$$\hat{\omega}^{sw}_{agr}(t) = \begin{cases} \omega^{sw}_{agr} + \pi^{sw}_{agr} \cdot (\frac{\overline{P}-P(t)}{\overline{P}} \cdot \gamma \cdot \hat{\zeta} + \frac{E(t)-\overline{E}}{\overline{E}} \cdot \omega^{sw}_{agr}) & \text{if } P(t) < \overline{P}, \\ \\ \omega^{sw}_{agr} + \pi^{sw}_{agr} \cdot (\frac{E(t)-\overline{E}}{\overline{E}} \cdot \omega^{sw}_{agr}) & else, \end{cases}$$

$$\hat{\omega}^{gw}_{agr}(t) = \begin{cases} \omega^{gw}_{agr} + \pi^{gw}_{agr} \cdot (\frac{\overline{P}-P(t)}{\overline{P}} \cdot \gamma \cdot \hat{\zeta} + \frac{E(t)-\overline{E}}{\overline{E}} \cdot \omega^{gw}_{agr}) & \text{if } P(t) < \overline{P}, \\ \\ \omega^{gw}_{agr} + \pi^{gw}_{agr} \cdot (\frac{E(t)-\overline{E}}{\overline{E}} \cdot \omega^{gw}_{agr}) & else, \end{cases}$$

$$\hat{\zeta} = \begin{cases} \frac{\overline{P}-P(t)}{\overline{P}}\zeta, & \text{if } P(t) < \overline{P}, \\ \\ 0, & else. \end{cases}$$

Water module - Grey water demand

$$w_s^k(t) = \frac{\delta_2^k \cdot c_{p,s}^k - \hat{c}_s^k(t)}{\delta_1^k \cdot \hat{c}_s^k - c_0^k(t)} \cdot \rho_s^k(t)$$

$$c_0^k(t) = \begin{cases} c_{min}^k, & \text{if } \pi^k(t) \leq \pi_{min}^k, \\ \alpha \cdot \pi^k(t) + b(\alpha), & \text{if } \pi_{min}^k < \pi^k(t) < \pi_{max}^k \\ c_{max}, & else. \end{cases}$$

$$\hat{c}_s^k = \begin{cases} c_s^k, & \text{if } c_0^k \leq c_s^k, \\ c_0^k, & else. \end{cases}$$

Water module - Water feasible supply

$$E(P,T) = a_E + \beta_1 \cdot P + \beta_2 \cdot T + \epsilon_E,$$

$$R(P,E) = a_R + \beta_3 \cdot P + \beta_4 \cdot E + \epsilon_R,$$

$$G(P,E) = a_G + \beta_5 \cdot P + \beta_6 \cdot E + \epsilon_G,$$

$$\hat{R}(t) = \begin{cases} R_t - \psi \overline{R} & \text{if } \psi \overline{R} \leq R(t) \leq (\mu + \psi) \cdot \overline{R}, \\ \mu \overline{R} & \text{if } (\mu + \psi) \cdot \overline{R} \leq R(t), \\ 0 & else, \end{cases}$$

$$\hat{G}(t) = \begin{cases} \overline{G} \cdot (1 - \lambda) & \text{if } G(t) \leq \overline{G} \cdot (1 - \lambda), \\ \overline{G} \cdot (1 + \lambda) & \text{if } G(t) \geq \overline{G} \cdot (1 + \lambda), \\ G(t) & else, \end{cases}$$

The Extended Water Exploitation Index (EWEI) for water body k is then given by the ratio between the extended water demand and feasibly supply.

Climate damage

- Climate damages reduce production efficiency: They are modeled as proportional reductions in output, applied by increasing technical coefficients in the input–output tables, meaning industries need more inputs to maintain output.
- Economic ripple effects: Higher intermediate demand raises output needs in upstream sectors, lowers value-added and profits (under rigid wages), and affects employment levels.
- Broader fiscal and sectoral impacts: Climate effects indirectly influence public spending (e.g., healthcare), tax revenues, and unemployment benefits through changes in income, output, and labor markets.

Adaptation

Let us define $a_{i,j}(t)$, the technical coefficient, representing the relation between sector j's output and its input from sector i. Introducing a sectoral climate damage multiplier $(1 - \Lambda_j(t)) \in [0, 1]$, in every period t we have that the technical coefficient is $\frac{a_{i,j}(t)}{1-\Lambda_j(t)}$. The adaptation policy proportionally reduces the magnitude of $\Lambda_j(t)$ by means of parameter $\alpha(t)$. Thus, the impact of climate change becomes $\frac{a_{i,j}(t)}{1-\alpha(t)\Lambda_j(t)}$, with

$$\alpha(t+1) = \alpha(t) - \beta \cdot S(t), \ or \tag{20}$$

$$\Delta\alpha(t) = -\beta \cdot S(t), \tag{21}$$

where $S(t)$ is the adaptation expenditure, in billion euros, and β is the effectiveness or efficiency of adaptation expenditure.

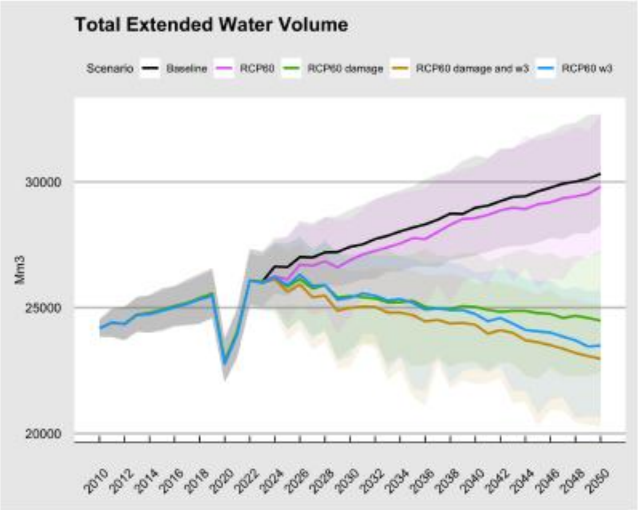
Scenarios – Base and Climate Change

Table 1: Summary of the main assumptions for every scenario.

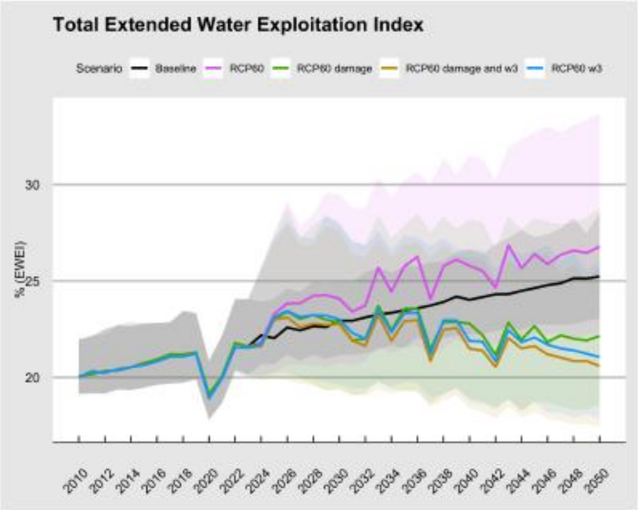
Scenarios	*Climate change*	*Water efficiency*	*Economic damage*	*Adaptation*
BAU				
RCP 6.0	✓			
RCP 6.0 eff	✓	✓		
RCP 6.0 damage	✓		✓	
RCP 6.0 adapt eff	✓	✓	✓	✓

Water efficiency is assumed to represent an external enhancement in water efficiency by 20% by the year 2050 (Δ_{ω}^{20}).

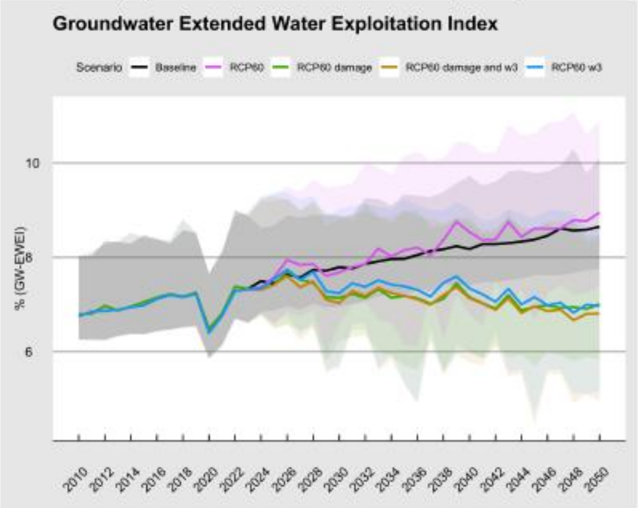
III. Results



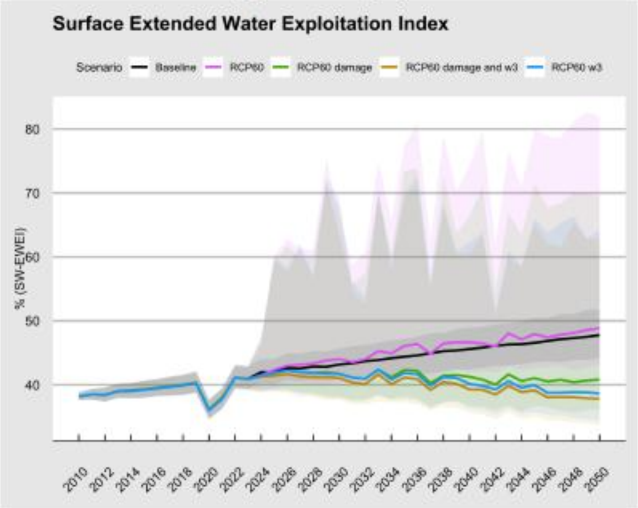
(a) Water extended demand (total)



(b) EWEI (%)

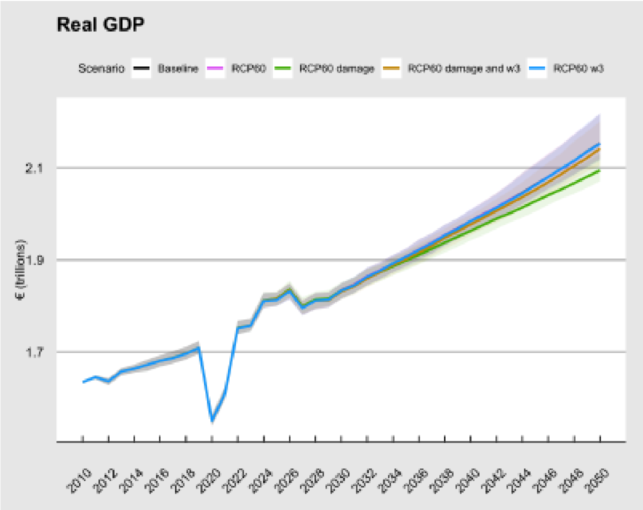


(c) EWEI GW (%)

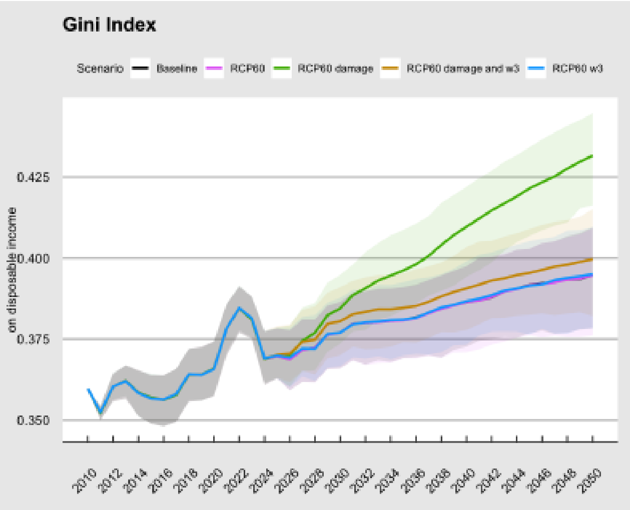


(d) EWEI SW (%)

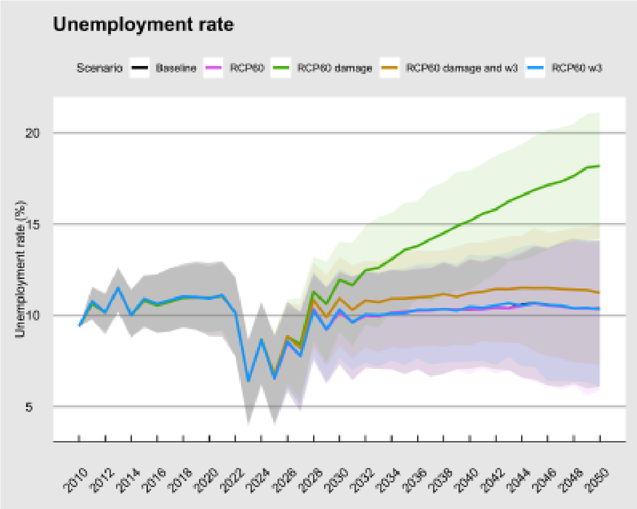
Figure 2: Scenario analysis of environmental indicators. The solid lines and shaded areas around them indicate the medians and 95% confidence intervals, respectively, out of 500 independent simulations.



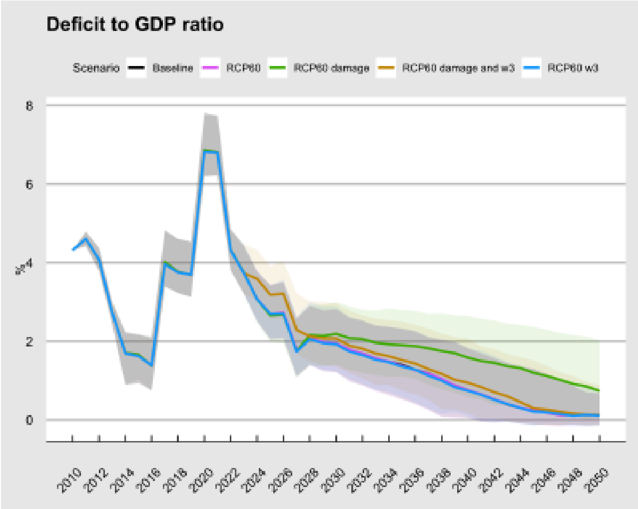
(a) Economic growth



(b) Income inequality



(c) Unemployment rate



(d) Public deficit-to-GDP rate

Figure 3: Scenario analysis of economic and social indicators. The solid lines and shaded areas around them indicate the medians and 95% confidence intervals, respectively, out of 500 independent simulations.

V. Conclusions

Conclusions

- Climate change and economic growth can exacerbate water stress, especially in agricultural regions of southern Italy, if adequate integrated water management policies are not implemented.
- The interaction between the economy and water has amplifying effects, where water limitations reduce agricultural and industrial production, which in turn hampers economic growth.
- The integrated model helps identify more effective policies, showing that strategies such as improving water-use efficiency or reallocating sectoral water use can mitigate the impact of climate change on water resources and the economy.


MUCHAS GRACIAS