



Supplement of

Cooperation in a transboundary river basin: a large-scale socio-hydrological model of the Eastern Nile

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Supplement

Table S1: Individual variables and corresponding data sources used by Food and Agriculture Organization Data (2020b) for estimating the political stability index (Worldwide Governance Indicators, 2021)

Variables	Sources
Orderly transfers	Economist Intelligence Unit Riskwire & Democracy Index
Armed conflict	
Violent demonstrations	
Social unrest	
International tensions / terrorist threat	
Political terror scale	Cingranelli Richards Human Rights Database and Political Terror Scale
Security risk rating	iJET Country Security Risk Ratings
Intensity of internal conflicts: ethnic, religious, or regional	Institutional Profiles Database
Intensity of violent activities of underground political organizations	
Intensity of social conflicts (excluding conflicts relating to land)	
Government stability	Political Risk Services International Country Risk Guide
Internal conflict	
External conflict	
Ethnic tensions	
Protests and riots	Global Insight Business Conditions and Risk Indicators
Terrorism	
Interstate war	

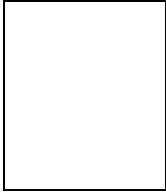
Table S2: List of Abbreviations

Abbreviation	Explanation
BC	Basin-wide Cooperation
C&C	Conflict and Cooperation
CFA	Cooperative Framework Agreement
CS	Cooperation Status
ENB	Eastern Nile Basin
ENSH	Eastern Nile Basin Socio-hydrological
FC	Food Consumption
FDI	Foreign direct investment
FP	Food Production
GERD	Grand Ethiopian Renaissance Dam
HAD	High Aswan Dam
HP	Hydropower Generation
JMP	Joint Multipurpose Project
NBI	Nile Basin Initiative
PDC	Potential Dam Capacity
PEC	Potential Energy Capacity
PS	Political Stability
S	Reservoir Storage under Construction
SWAT	Soil Water Assessment Tool
TECCONILE	Technical Cooperation Commission for the Promotion and Development of the Nile
VARS	Variogram Analysis of Response Surfaces
WC	Willingness to Cooperate

Table S3: Summary of the main equations, variables, and factors in the Eastern Nile Basin Socio-hydrological (ENSH) model

Model Component	Equation	Variables/Factors
Willingness to Cooperate	$WC_{Eth,t} = \left(\beta_{1,Eth} \cdot \left(\frac{FC_{Eth,t}}{FP_{Eth,t}} \right)^{-1} + \beta_{2,Eth} \cdot \left(\frac{PEC_{Eth,t}}{HP_{Eth}} \right)^{-1} + \beta_{3,Eth} \cdot \frac{S_{Eth,t}}{PDC_{Eth}} \right)^{\alpha_{1,Eth}} \cdot (1 - PS_{Eth,t})^{\alpha_{2,Eth}} \cdot (1 - FDI_{Eth,t})^{\alpha_{3,Eth}} \cdot \left(\frac{CS_{Eth,t}}{n} \right)^{\alpha_{4,Eth}} \quad (1)$	<p>WC_t (-): countries' willingness to cooperate at time t</p> <p>β_1, β_2, and β_3 (-): countries' emphasis on the food gap, the energy gap, and future reservoir storage</p> <p>FC_t (kg): countries' food consumption at time t</p> <p>FP_t (kg): countries' food production at time t</p> <p>PEC_t (MW): countries' potential energy capacity at time t</p> <p>HP (MW): countries' energy production</p> <p>S_t (m³): countries' reservoir storage under construction at time t</p> <p>PDC (m³): countries' potential dam capacity</p> <p>$\alpha_1, \alpha_2, \alpha_3$, and α_4 (-): countries' emphasis on multiplicative variables of decision making</p> <p>PS_t (-): countries' relative political stability at time t</p> <p>FDI_t (-): countries' foreign direct</p>
	$WC_{Sud,t} = \left(\beta_{1,Sud} \cdot \frac{FC_{Sud,t}}{FP_{Sud,t}} + \beta_{2,Sud} \cdot \frac{PEC_{Sud}}{HP_{Sud,t}} + \beta_{3,Sud} \cdot \frac{S_{Sud,t}}{PDC_{Sud}} \right)^{\alpha_{1,Sud}} \cdot (1 - PS_{Sud,t})^{\alpha_{2,Sud}} \cdot (1 - FDI_{Sud,t})^{\alpha_{3,Sud}} \cdot \left(\frac{CS_{Sud,t}}{n} \right)^{\alpha_{4,Sud}} \quad (2)$	
	$WC_{Egy,t} = \left(\beta_{1,Egy} \cdot \frac{FC_{Egy,t}}{FP_{Egy,t}} \right)^{\alpha_{1,Egy}} \cdot (1 - PS_{Egy,t})^{\alpha_{2,Egy}} \cdot (1 - FDI_{Egy,t})^{\alpha_{3,Egy}} \cdot \left(\frac{CS_{Egy,t}}{n} \right)^{\alpha_{4,Egy}} \quad (3)$	

		investment at time t CS_t (-): countries' memory of cooperation at time t n (-): the total number of riparian countries (i.e., 3)		
The Memory of Cooperation	$ST_{k,t} = \gamma_{k,1,1} \cdot \overline{WC}_{-k,t-1} + \gamma_{k,1,2} \cdot \overline{WC}_{-k,t-2} + \dots + \gamma_{k,1,m} \cdot \overline{WC}_{-k,t-m}$ $ST_{k,2,t} = \gamma_{k,2,1} \cdot \overline{WC}_{-k,t-1} + \gamma_{k,2,2} \cdot \overline{WC}_{-k,t-2} + \dots + \gamma_{k,2,m} \cdot \overline{WC}_{-k,t-m}$ \vdots $ST_{k,i,t} = \gamma_{k,i,1} \cdot \overline{WC}_{-k,t-1} + \gamma_{k,i,2} \cdot \overline{WC}_{-k,t-2} + \dots + \gamma_{k,i,m} \cdot \overline{WC}_{-k,t-m}$ $\varepsilon_{k,i,t} = ST_{k,i,t-1} - \overline{WC}_{-k,t-1} + ST_{k,i,t-2} - \overline{WC}_{-k,t-2} + \dots + ST_{k,i,t-m} - \overline{WC}_{-k,t-m} $ $\hat{\Phi}_{k,t} = \min\{\varepsilon_{k,1,t}, \varepsilon_{k,2,t}, \dots, \varepsilon_{k,i,t}\}$ $CS_{k,t} = CS(ST_{k,i,t} \hat{\Phi}_{k,t})$	<p>(4)</p> <p>(5)</p> <p>(6)</p> <p>(7)</p>	$S_{k,1,t}$ (-): the i th strategy of country k at time t $\gamma_{k,i,m}$ (-): the weight for the i th strategy at time $t - m$ $\overline{WC}_{-k,t-m}$ (-): the average of the countries' willingness to cooperate but country k at time $t - m$ m (-): memory span i (-): number of strategies $\varepsilon_{k,i,t}$ (-): the residual of the i th strategy for country k at time t $\hat{\Phi}_{k,t}$ (-): the minimum residual of different strategies included in a bag of strategies for country k at time t	
	Basin-wide Cooperation	$BC_t = \frac{1}{3} \times (WC_{Eth,t} + WC_{Sud,t} + WC_{Egy,t})$	(8)	BC_t (-): basin-wide cooperation
	Food Production	$FP_{Eth,t} = A_{ig,Eth,t} \cdot CY_{ig,Eth,t} + A_{rf,Eth,t} \cdot CY_{rf,Eth,t}$	(9)	A_{ig} (m ²): countries' actual irrigated and rainfed areas
		$FP_{Sud,t} = A_{ig,Sud,t} \cdot CY_{ig,Sud,t} + A_{rf,Sud,t} \cdot CY_{rf,Sud,t}$	(10)	A_{rf} (m ²): countries' actual rainfed areas
		$FP_{Egy,t} = A_{ig,Egy,t} \cdot CY_{ig,Egy,t}$	(11)	CY_{ig} (kg/m ²): countries' crop



yields in irrigated
areas
 CY_{rf} (kg/m²):
countries' crop
yields in rainfed
areas