Modelling the role of the water-food nexus in Central American urban human conflicts through Bayesian Econometric Zero-inflated Poisson Model

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Over the past decade, research has shown that hydroclimatic extremes may enhance conflict in fragile societies (Kallis & Zografos, 2014; Mach et al., 2019; Zografos et al., 2014). However, most of quantitative studies try to explain the climate-conflict nexus dwelling on the observation of hydroclimatic shocks, using rainfall deviation indices e.g., SPEI, (Hendrix & Salehyan, 2012; Von Uexkull et al., 2016), rather than on their effects on the water-food system. With the aim of going beyond 'the water leads to war thesis'(Dell'angelo et al., 2018), we explore the nexus between water, food and human conflicts in Central America, addressing the role of the bio-physical effects of the droughts on water and food, in influencing urban conflicts. We use a physically based agro-hydrological model (Chiarelli et al., 2020) to assess the time and spatial effects of the droughts on water availability for agricultural production, and, in turn, food security. Then we apply a Bayesian Zero-inflated Poisson Model (Equation 1) to predict the number of conflict occurrences and detect spatio-temporal relation among social and hydrological variables over the entire study area. Bayesian inference is chosen to avoid the risk of overfitting, due to the presence of several heterogeneous parameters (Epifani et al., 2020), and an independent and efficient model design (Gleditsch, 2012; Raleigh et al., 2010) is adopted, by selecting a square grid with a spatial resolution of 20 km x 20 km and a time dimension of one year.

$$\begin{cases} P(\underline{Y}_{it} = 0) = \pi_{it} + (1 - \pi_{it})e^{-\lambda_{it}} \\ P(\underline{Y}_{it} = k) = (1 - \pi_{it})Poisson_{\lambda}(k), \quad k = 1,2,\dots \end{cases} \tag{1}$$

The spatial autocorrelation is modelled via a Spatially Lagged Explanatory Variables X (SLX) model (Elhorst, 2001), through exogenous spatial interaction effects among covariates, involving neighboring spatial units, namely spatial spillovers (Epifani et al., 2020). Conditionally Autoregressive (CAR) random effects have also been implemented for alternatively modelling of local spatial spillovers, by the average of neighboring grid random effects. However the best fit of the data is obtained with the SLX model, confirming that SLX is the simplest econometric implementation to model flexibly spatial spillovers (Elhorst et al., 2014; Epifani et al., 2020).
The Poisson parameter λ is modelled in Equation (2):

$$\log \lambda_{it} = \boldsymbol{\beta}_{0_t} + \boldsymbol{\beta}_t \mathbf{X}_t + \boldsymbol{\delta}_t \mathbf{W}_{it} \mathbf{X}_t \tag{2}$$

and the selected logistic probability distribution is given in Equation (3):

$$\text{logit}(\pi_{it}) = \boldsymbol{\gamma}_{0_t} + \boldsymbol{\gamma}_t \mathbf{X}_t \tag{3}$$

where, $\boldsymbol{\beta}_t$ and $\boldsymbol{\gamma}_t$ are the vectors of the regression coefficients, accounting for direct spatial effects, related to the matrix $\mathbf{X}_t$ of the exogenous explanatory variables (*population density*, *Sub-Human Development index*, *green water availability* (Chiarelli et al., 2020), *food security index* and *trade dependency*), and $\boldsymbol{\beta}_{0t}$ and $\boldsymbol{\gamma}_{0t}$ are the error terms. The spatial spillovers are expressed by $\boldsymbol{\delta}_t$ coefficients, associated to the neighbouring values of exogenous variables, identified through the first-order contiguity matrix $\mathbf{W}_{it}$.

Our results show that droughts-induced water deficit affects food security in the cities, due to the strong nexus among water and food, and the latter, in turn, influences conflict rise. Our analysis provides a comprehensive and theoretically consistent statistical tool able to capture the role of water and food in the droughts-conflict nexus, showing that the surplus redistribution through food trade crucially influences human livelihoods and security of urban-deficit areas.

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