Approximating Network Dynamics in the Classic Maya Collapse

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In his 1985 book "The Dynamics of Apocalypse: A Systems Simulation of the Classic Maya Collapse," Lowe proposed a three-state system to model the warfare component of the Classic Maya collapse. He assumed the Classic Maya formed a system of independent city-states, where each city-state was either marginally stable, in crisis mode, or collapsed. His equations for this model are similar to the mean-field SIR model (S=Susceptible, I=Infected, R=Recovered), where each agent can interact with all other agents, and includes terms representing fighting between stable and crisis sites, fighting among crisis sites (called backwash), and an external pressure term. In the Lowe case, fighting can transmit "crisis" instead of disease, and although crisis sites can recover, they can also collapse. According to Lowe, the external pressure term expresses the effect of external forces on stable sites so that the larger the number of sites in crisis (and thus fighting with stable sites), the more likely non-Maya outsiders will drive a stable site into crisis.

We reproduce Lowe's model using system dynamics, and provide a more realistic version of the model, where each site can interact with an average number of sites instead of all sites. Recently, Lamberson (2017) introduced to the system dynamics community a pair-wise modeling approach to approximate network dynamics in SIR-like models. It typically applies to models of infectious disease spread, and is relatively new to system dynamics modeling. To approximate network dynamics in the Lowe case, we use this approach.

We show that the network dynamics model without the backwash and external pressure term provides a better fit to the reference data than Lowe's mean-field model. We also extend the pair-wise SIR-like model (in general) to include situations where births (of city states) are not equal to deaths (collapse).

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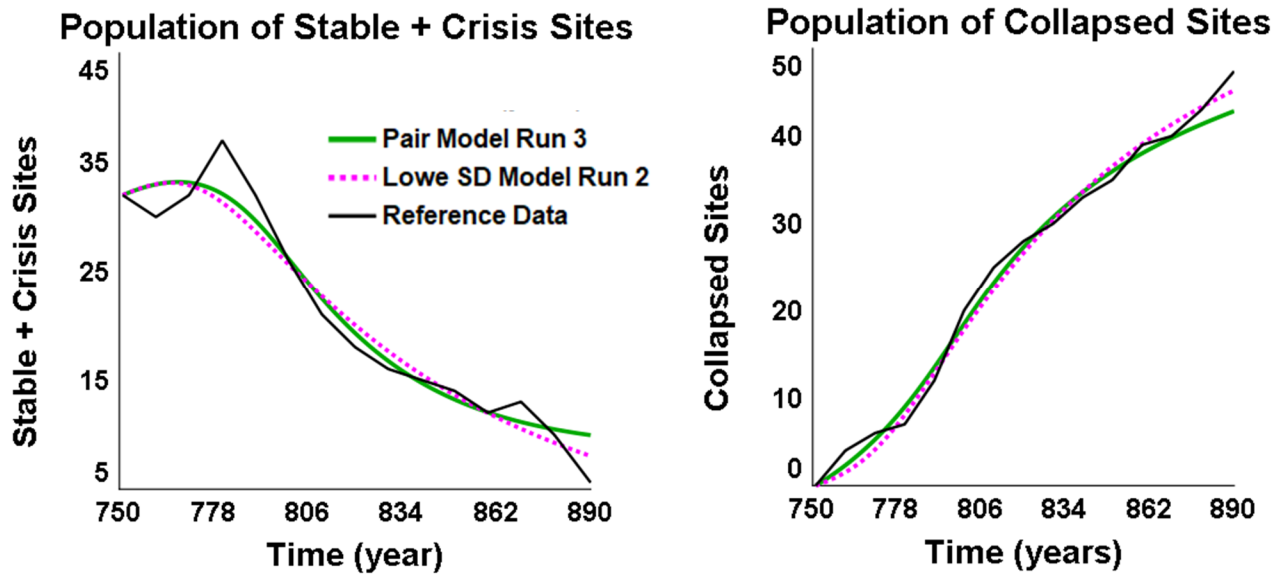
Lowe modeled the collapse of the Classic Maya in the eighth and ninth centuries A.D (1985). Lowe (1985) wrote: “the Southern Maya Lowlands formed a system of states, fragmented politically, but united by a common cosmology, religious pantheon, writing system, elite culture, and effectively congruent social organization (roughly, the “city state”)” (p.7).

For this work, we accept Lowe’s (1985) definition of collapse: in a period of 100 to 150 years, nine-tenths of the population disappeared. Lowe (1985) describes the collapse in the following way: “…[the] burgeoning population growth…had produced serious ecological stresses and that these, together with internal contradictions within the Classic Maya society itself, had by c. A.D. 750 moved the system of states …into a marginally unstable position - a state of affairs that, given the dense population but dispersed settlement pattern, propagated catastrophe from one site to the next across the Southern Maya Lowlands” (p.7). Lowe (1985) used Maya sites that produced dated monuments as the source of his reference data. For each site, he listed: its name, its first legible dated monument, its last dated monument and the source of the data. The dated monuments served as a proxy for the birth and death of a Maya city-state.

The following figure provides a comparison between the Lowe SD model run, the pair-wise model run and the reference data. Both runs are close to the reference data with the pair-wise model fitting a little better, especially for the “stable + crisis sites” plot. As mentioned earlier, unlike the Lowe SD model, the pair-wise model did not need the backwash term that represents fighting among the crisis sites or the external pressure term.



We demonstrated the value of the pair-wise modeling approach within System Dynamics by successfully applying it to this non-trivial problem.

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