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Development of a Model of Interaction Between Civilian, Soldier and Non-State Armed Group Populations Using Ecological Methods

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Abstract

An age structured population model with a resource-mandated carrying capacity was utilized to simulate a human population participating in a resource-based economy, and an intraspecific competition or 'harvesting' model was developed and employed to approximate interactions between civilian, soldier, and non-state armed group or NSAG sub-populations. Equilibria in which an NSAG and governmental army eliminate each other, the NSAG supersedes the state, or the government destroys the NSAG with varying margins and timescales of victory were discovered. If a non-state armed group has primarily financial, as opposed to ideological underpinnings, its growth and harvesting of productive adults from the civilian population should contribute to deterioration of a resource-based economy. Moreover, a minimum noncombatant

Introduction

- Regional warming impacts will increasingly manifest themselves as localized food and water insecurity [13] and the destabilization of tropical and subtropical resource-based economies [16]. They are expected to facilitate the replacement of states' monopolies on the use of force in areas of weak governance with non-state armed groups [17].
- Latin America's often low levels of rural development, environmental degradation [13] and over-reliance on traditional albeit climate-sensitive crops [16] make people vulnerable to the impacts of climate change, incentivizing illegitimate labor and contributing to forced urbanization [17].
- Economic competition related to natural resource pressure tends to preclude instability and even violent conflict in the absence of effective resolution protocols [17].
- Filling extreme-event related 'governance voids' in northern Guatemala [4], rural Colombia and Nicaragua as well as other countries [2], narco-traffickers and extremist political factions establish alternative state-like structures to provide basic services to the local population, developing localized pockets of authority which supersede the State [17].
- The many steps in any comprehensive and causative climate-conflict pathway are difficult to conceptualize, complicated to model, and in need of sociological substantiation [13].

Sub-Population Derivatives: Harvesting [15]

Temporal Derivatives of Sub-Populations XI, NSAG; XS, Soldiers; XC, Civilians

$$XIDeriv := \frac{\tau I \cdot XI(t) \cdot XC(t)}{XS(t) + halfSatFractI \cdot XI(t)} - \left(\left((XS(t)+1)/(XI(t)+1)\right) + \mu\right) \cdot XI(t)$$

$$XSDeriv := \frac{\tau S \cdot XS(t) \cdot XC(t)}{XI(t) + halfSatFractS \cdot XS(t)} - \left(\left((XI(t)+1)/(XS(t)+1)\right) + \mu\right) \cdot XS(t)$$

$$XCDeriv := (\alpha - \delta) \cdot X0 - (\mu) \cdot XC(t) - \frac{\tau S \cdot XS(t) \cdot XC(t)}{XI(t) + halfSatFract \cdot XS(t)} - \frac{\tau I \cdot XI(t) \cdot XC(t)}{XS(t) + halfSatFract \cdot XI(t)}$$

Timescales of Recruitment into XI, XS

$$\tau S := 90.36 + \left(subs([\theta = 0.6, \sigma = 0.6], BI(t))\right)$$

$$\tau S := 90.36 + \frac{XI(t)^{0.4}}{XI(t)^{0.4} + XS(t)^{0.6}}$$

$$\tau I := 90.36 + subs([\theta = 0.6, \sigma = 0.6], BI(t)) + Rins \ \#resource\ insufficiency$$

$$\tau I := 90.36 + \frac{XI(t)^{0.4}}{XI(t)^{0.4} + XS(t)^{0.6}} + 3.801632764\ 10^{-11}\ R(t)$$

Probability of Local NSAG Monopoly on the Use of Force

$$BI := t \mapsto \frac{XI(t)^{1-\theta}}{XI(t)^{1-\theta} + XS(t)^{\sigma}}$$

Θ, σ are technical parameters dictating NSAG advantage [8]

Results*: Model Output for Projected Conflict in Valle del Cauca, Colombia (timesteps from blue star to red star)

Figure 1: Projected Valle del Cauca Conflict in XS, XI, XC 3-Space

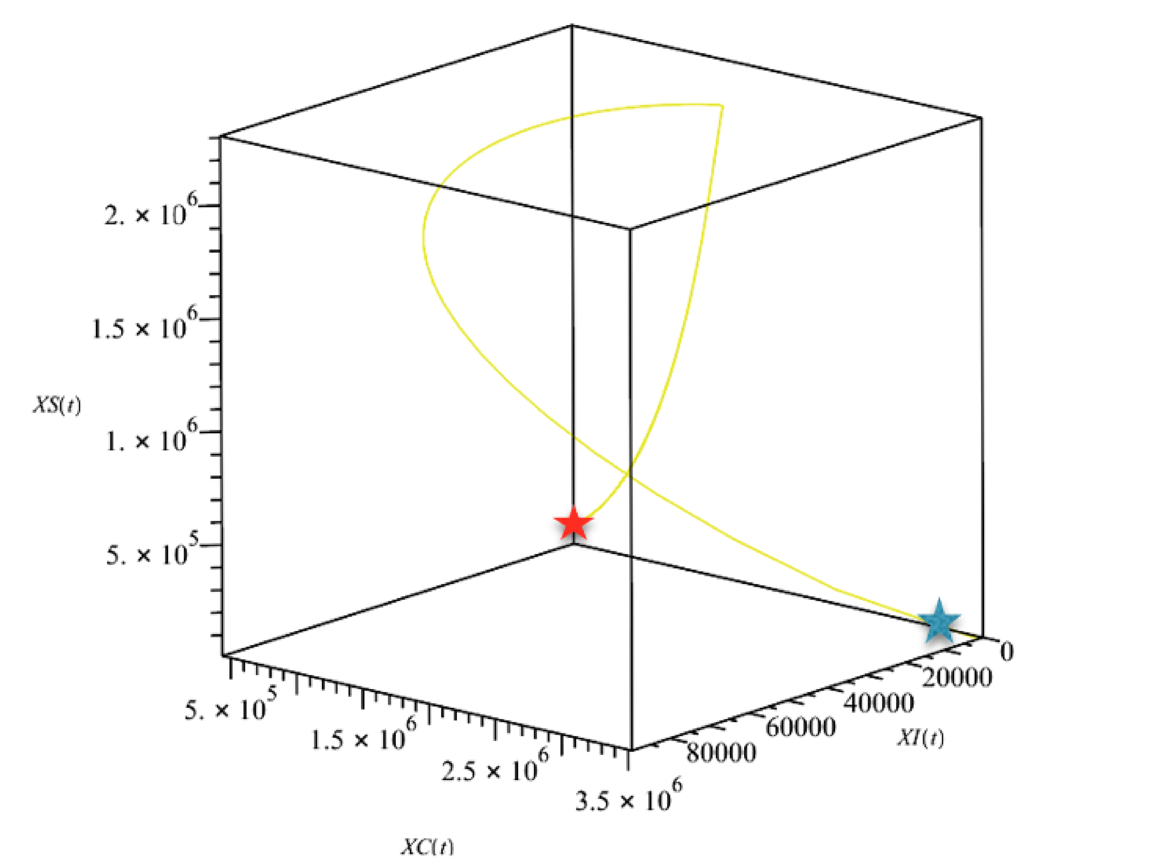
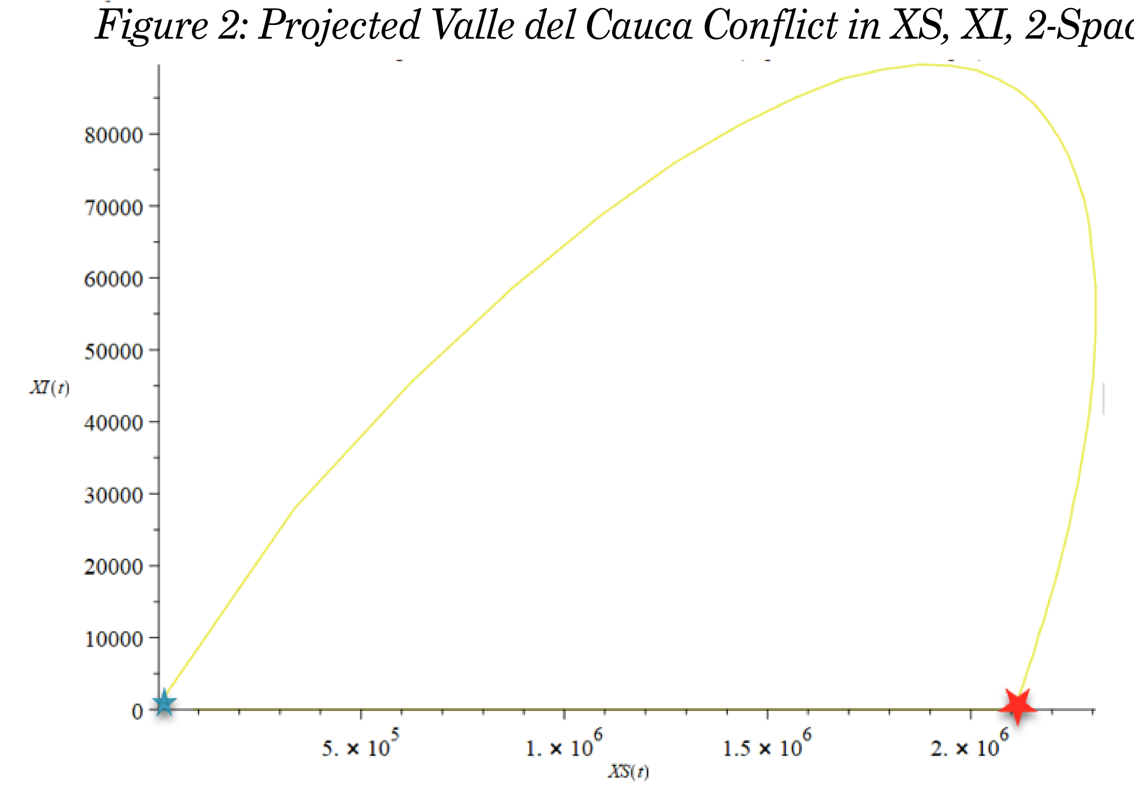


Figure 2: Projected Valle del Cauca Conflict in XS, XI, 2-Space



Figures 1-2 exhibit the projected changes in the Soldier, Civilian, and NSAG sub-populations over a 10-year model run. The NSAG 'Black Eagles' is known to be active in Colombia's Cauca Province and possesses ~1200 members [6] (the initial XI in the run). There are ~8000 soldiers in Valle del Cauca at a given time [4]; 8000 is the initial XS.

Figure 3: Initial Resource Base for Given Xo, Dependent Population & X1, Productive Adult Population

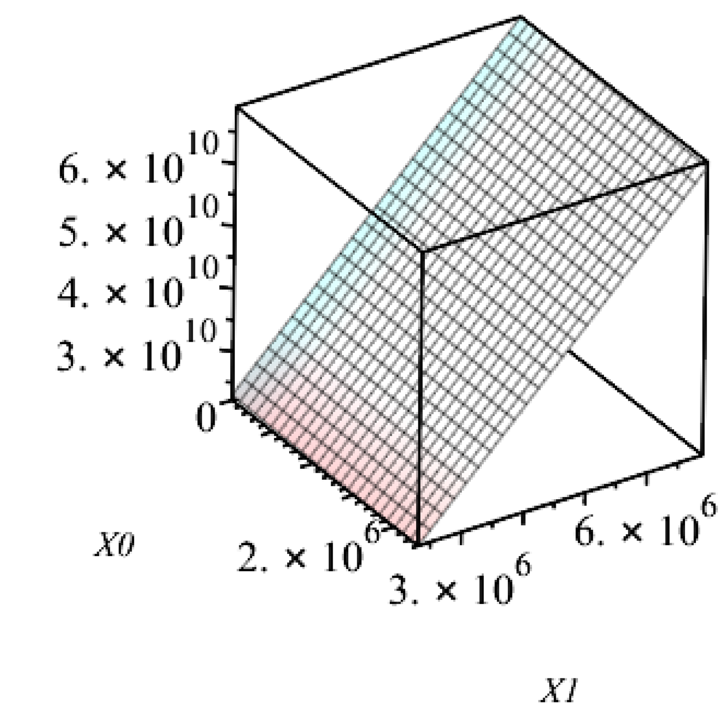
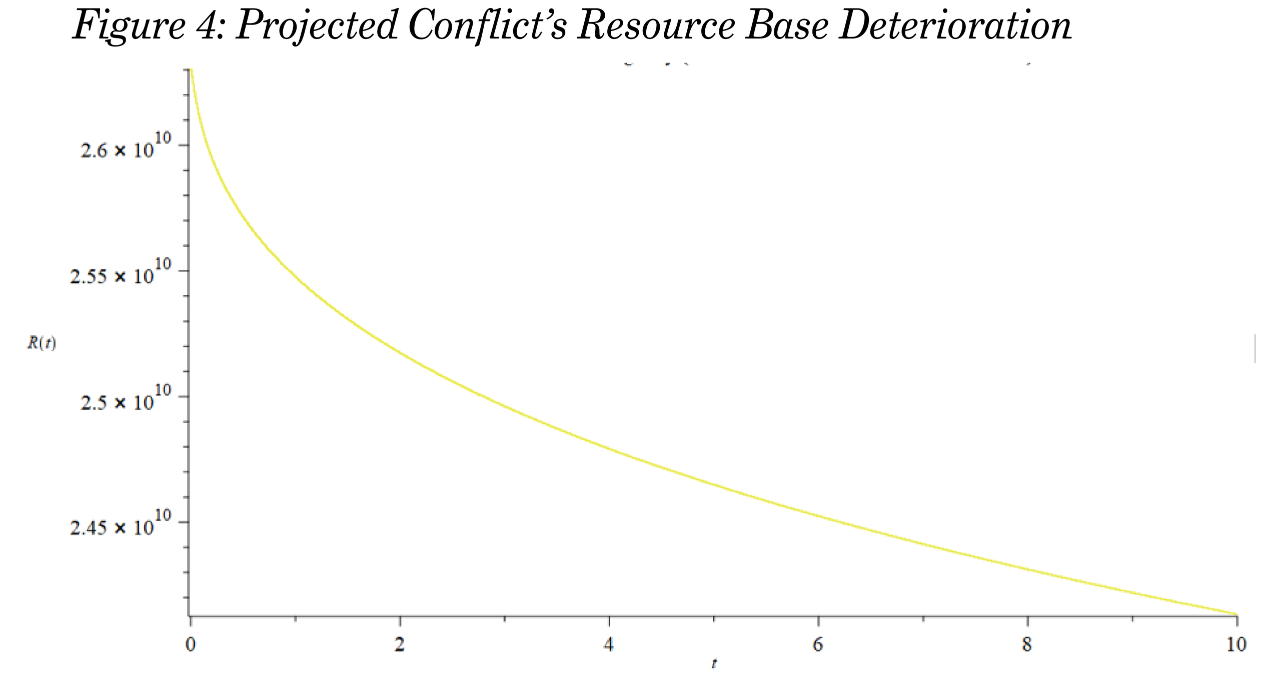


Figure 4: Projected Conflict's Resource Base Deterioration



Figures 3-4 respectively exhibit the steady-state, initial Resource Base as a function of adults, X1, and dependents, Xo, and the projected deterioration of the Resource Base imposed by a conflict between the government and NSAG. Units of resources, R(t) are approximated to USD.

Figure 5; Alternative Equilibrium 1: NSAG Numerical Advantage

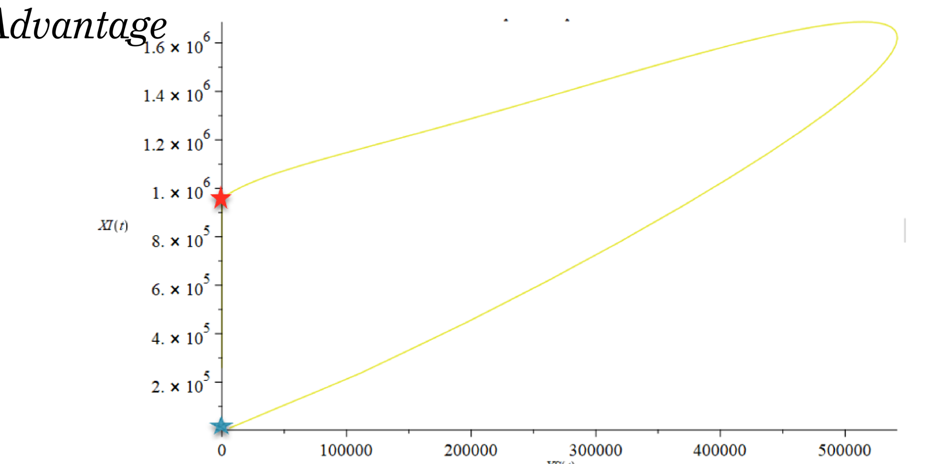


Figure 6; Alternative Equilibrium 2: NSAG Victory Near Critical Point

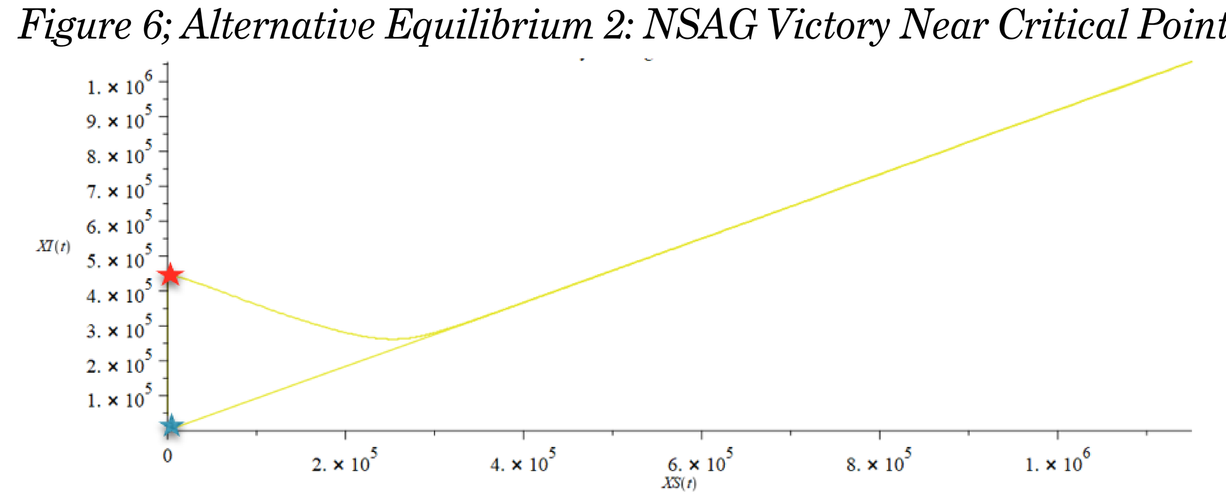
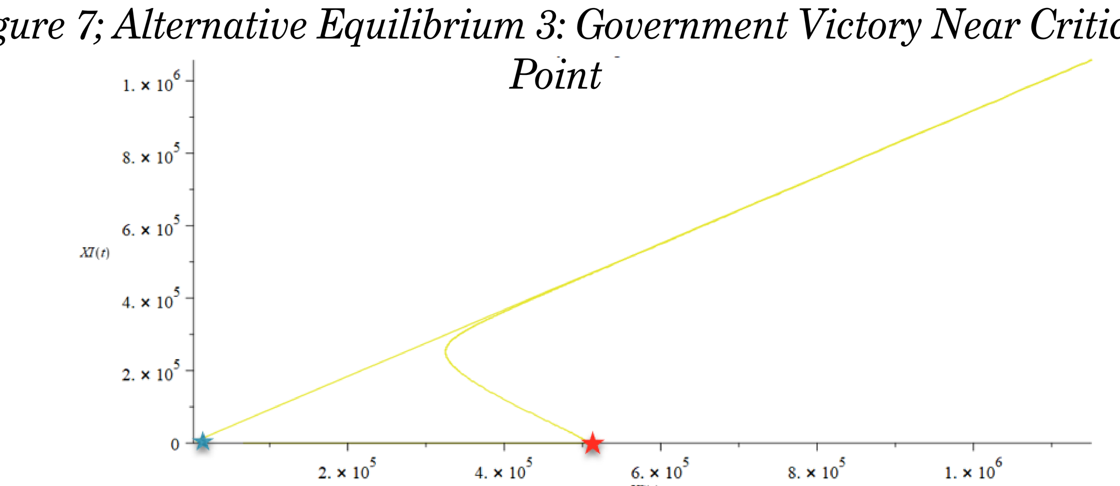


Figure 7; Alternative Equilibrium 3: Government Victory Near Critical Point



Figures 5-7, above, demonstrate three of the 4 other possible paths to an equilibrium state, depending on initial conditions. Figure 5 shows the NSAG winning by a wide margin and thus a 'mirror' of Figure 2. Figures 6-7 show NSAG and army victories in the vicinity of the critical point.

*Software Employed in Generating Output

Equations, outputs, and figures shown were generated using the mathematical programming software Maple, a variant of Matlab. Model development, testing, and modification specifically utilized Maple's DE Tools package and documentation, which employs a Runge-Kutta method to accomplish time-stepping through state space.

Age-Structured Model

Birth Rate, Adult & Youth Death Rates

$$\beta := \beta 0 + \beta 1\ X1 + \beta R\ R^{n}$$

$$\mu := \mu 0 + \mu 1\ X1 + \mu R\ R^{n}$$

$$\delta := \delta 0 + \delta 1\ (X1 + X0) + \delta R\ R^{n}$$

Rate of Change of Adults (X1), Youth (X0)

$$\frac{\partial}{\partial t} X1 := (\alpha - \delta)\ X0 - \mu\ X1$$

$$\frac{\partial}{\partial t} X0 := -\alpha\ X0 + \beta\ X1$$

XI: NSAG or Insurgents
XS: Soldiers
XC: Civilians

Form of Steady State Solutions

Steady States for Soldiers, NSAG/Insurgents, Civilians (found algebraically, substantiate 5 equilibria)

$$exprS0 := Los\ C + \frac{L1\ s\ ZI\ C}{ZI + ZS} - \left(\frac{gs\ ZI^2}{ZS^2} - \mu\right) ZS^2 + drs\ R\ ZS^2$$

$$exprI0 := Loi\ C + \frac{L1i\ ZI\ C}{ZI + ZS} - \left(\frac{gs\ ZS^2}{ZI^2} - \mu\right) ZI^2 + dri\ R\ ZI^2$$

$$\frac{Kr\,\gamma R(t)\,\beta - Kr\,\gamma R(t)\,d0 - Kr\,\gamma Ro\,\beta + Kr\,\gamma Ro\,d0 + \gamma R(t)\,R\,\beta - \gamma R(t)\,R\,d0 - \gamma R\,Ro\,\beta + \gamma R\,Ro\,d0 - Ro\,d0\,e + \mu\,e\,Ro}{d1\left(Kr\,\gamma R(t) - Kr\,\gamma Ro + \gamma R(t)\,R - \gamma R\,Ro + e\,Ro\right)}$$

Discussion, Conclusions

- Five equilibrium states were discovered: a trivial case and victories for the government or NSAG with varying margins.
- Coexistence of both the State and NSAG is highly unstable.
- It is speculated that climactic disruptions of resource-based economies may ease recruitment into NSAGs, although further research into climate-conflict relationships is required to substantiate any significant pathway.
- Easily implementable and contemporarily relevant parameter modifications include pandemic effects: COVID-19's simulated introduction to the system could be achieved by substantially increasing the crowding-related adult mortality term whilst leaving the youth mortality unchanged.
- The actions of the state and hiring of soldiers can effectively be approximated to the actions of a sole 'ruler' in the Latin American context with negligible lag, considering the contemporary regional tendency towards heavy concentration of political power in the executive [14].

Reference

1. Armitage, 2017 2. Barnet et al. 2007 3. Brasília et al. 2019 4. CIA, 2020 6. Colombia Reports 7. de Castro, 2016 8. Grossman, 1991 9. Hajat et al. 2011 11. Jervis, 1978 12. Leech, 2011 13. Levy, 2015 14. Montes-Niño, 2018 15. Olson, 2009 16. Rujano, 2014 17. Rüttinger et al. 2017 18. Wang et al. 2017

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