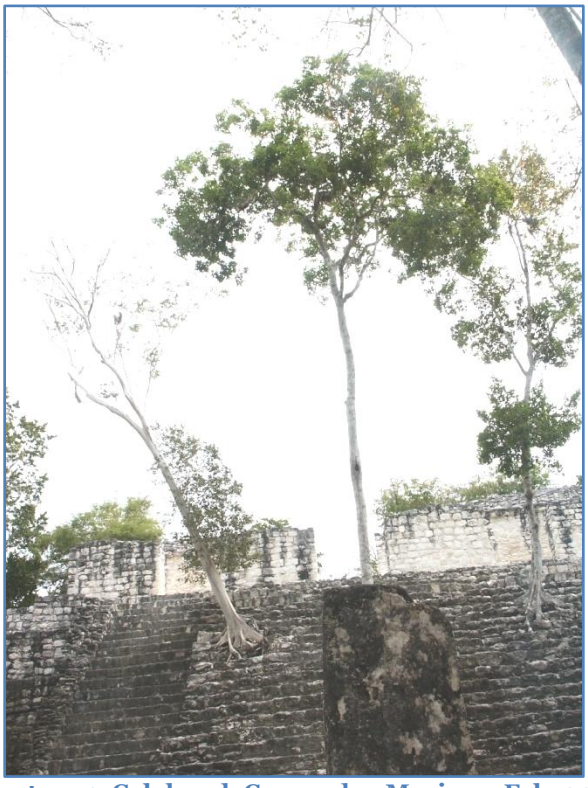
Maya Apocalypse: Warfare-Punctuated Equilibrium at the Limit of Growth

Tom Lum Forest
2023 18th Avenue
Forest Grove, Oregon USA 97116
1.503.359.3594
tforest@alum.mit.edu

Abstract
This paper explores the dynamics of population levels in Maya lowlands from the Late Preclassic to First Contact, roughly 500 BC–1500 AD. It starts with a simplified version of the Limits to Growth model (Meadows et al., 1993) and adds the effects of warfare on available production. Drawing also from the MIT paper "Simulation Model Development: A Case Study of the Classic Maya Collapse" (Runge et al., 1976), this paper illustrates how humans can politically intensify resource shortages into universal disaster. Written for presentation at the 2007 International System Dynamics Conference in Boston, Massachusetts, System Dynamicists with no prior knowledge of the Maya are the intended audience.



Structure 1, Calakmul, Campeche, Mexico – Feb. 2006

Introduction

The Late Preclassic (400 BC – 300 AD) and Classic Maya (300 AD – 900 AD) were the most sophisticated of native New World civilizations, thriving in what are now Guatemala, southern Mexico, and parts of Honduras and El Salvador. Maya hieroglyphics have been authoritatively deciphered in the last 30 years, bringing the Classic Maya from prehistory into history. Previous theories of peaceful Maya that prevailed into the 1970s notwithstanding, it seems that they were no more peaceful than their contemporaries in the Old World, or their successors everywhere. The current paradigm, as described in *Ancient Maya: The Rise and Fall of a Forest Civilization* by Arthur Demarest (Demarest 2004) and *The Fall of the Ancient Maya* by David Webster (Webster 2002), involves environmental factors and the changes in carrying capacity as before. But it also incorporates warfare–a lot of warfare: not just raiding parties to obtain hostages for ritual sacrifice, but full-scale, crop-burning, city-emptying warfare. This paper revisits the dynamics of Preclassic and Classic Maya civilization in light of the new paradigm.

Problem Statement

Why did Preclassic and Classic Maya civilization collapse? The reference mode is of s-shaped population growth to a crisis, with an abrupt collapse, rebounding slowly to another growth/collapse cycle. Why did the literate society that began before 500 BC in the Mirador Basin of Guatemala, building spectacular monuments dedicated with detailed chronicles of the birth, death, marriages and wars of its kings, come to an end in its Maya Lowland home? A shadow of it persisted in the northern Yucatan at Chichen Itza and Mayapán, among others, until the Spanish conquest. A Maya chieftaincy survived in Guatemala until 1697. There are over five million speakers of Maya languages in Mexico and Guatemala today. But the chronicles of kings are silent after 1000 AD, and grand palace complexes were built no more. In addition, population densities dropped substantially, and the mode of rule changed from a single *k'uhul ajaw* (divine king) to a *multepal* (council of nobles).

Initially influenced by the Olmec civilization of the Tabasco coast, Late Preclassic Mirador in the Petén of Guatemala had around 100,000 people in the first century AD, and was as large as any of its successors in the lowlands. It was abandoned shortly thereafter. From 150 AD – 250 AD, population was well below capacity. It took several centuries for the population to approach the earlier levels. In the meantime kingship had spread from the Mirador basin more broadly throughout the lowlands, and the pattern was repeated on a much larger scale.

Maya kings had, as we might say today, limited policy choices. Food production was handled locally, and trade in food was minimal. There was little irrigation or other economic infrastructure that required royal supervision or provided opportunity for royal management. Kings had two choices: build monuments or go to war. But those choices were related. When in stress, they went to war. When victorious in war, they built monuments. When defeated, they lost their lives and no monuments were built. In the apocalyptic wars of the eighth and ninth centuries, the divine lowland Maya kings

had no reverse gear, no peace treaties, and no choices. They were gods who conquered all problems militarily or died trying. International enmity was eternal.

In the aftermath, kingship itself was found wanting and was abolished, along with its military and architectural policies. Until the sixteenth century it continued with echoes of those policies, but politically the changes were irrevocable. Maya writing did not disappear altogether until after the Spanish arrived and Bishop Landa had his auto-de-fe in July 1562 (Landa 1566) to burn all the Maya codices, of which only four are known to have escaped. However, the astronomically sophisticated Long Count was forgotten and the breathtaking palace complexes of Palenque, Tikal, Copán, and Calakmul were covered and hidden by the forest, never to be reclaimed or replaced. Maya culture continues to this day. The *k'uhul ajaw* were no more.

Literature Review

The relevant System Dynamics literature on civilization-level dynamics is thin. *Classic Maya Collapse* (Runge *et al.*, 1976) is most relevant. Based on *The Classic Maya Collapse*, (1973 University of New Mexico Press ed. Patrick Culbert), it reflects the preeminence of the Peaceful Maya paradigm as championed by Eric Thompson (*The Rise and Fall of Maya Civilization*, 1966 Norman, OK: University of Oklahoma Press). Its premise is that the Maya elite were peaceful priest-kings who responded to stress by building ever-more monumental structures, thus indirectly lowering the productivity of the populace, who had to build more and farm less. In response to environmental crisis brought on by over-exploitation, it created a death spiral of falling yields causing less effort in farming, causing yields to fall faster. Jack Homer's *Civilization as Enterprise* (Homer 1978) and John Sterman's *Self-Organization, Competition, and Success in the Dynamics of Scientific Revolutions* (Sterman 1992) are also related in topic. Homer's formulations include resourced-based carrying capacity, but consider military involvement as a productivity-enhancing factor without consideration of warfare. Sterman's formulations can be applied to cultural paradigms and revolutions as well as scientific ones. But they are focused on "the sociological dynamics of paradigms as they compete against one another for members… [and examining] the role of intrinsic versus contextual factors in determining paradigm [sic] success." (Sterman 1992, op. cit., p. 1)

I have presented three related papers at previous International System Dynamics Conferences: "Sustainable Civilization: Cohesion, Capacity, and External Contacts," Tokyo, 1995; "Byzantine, Bulgarian, and Ottoman: The Dynamics of Empire at the Crossroads of Asia and Europe" Istanbul, 1997; and "The Perilous Frontier: East Asian Cultural Ecology and Two Millennia of Chinese Dynastic Succession," Quebec City, 1998. In all three, while internal resource constraints are included, the emphasis is on dynamics between states. My previous papers make use of the concept of social cohesion, and are more general (and complicated) in their models, as they broadly address multiple modes.

In contrast to my previous papers, this paper focuses on one mode: the steady population growth and catastrophic collapse of a civilization, caused by a policy

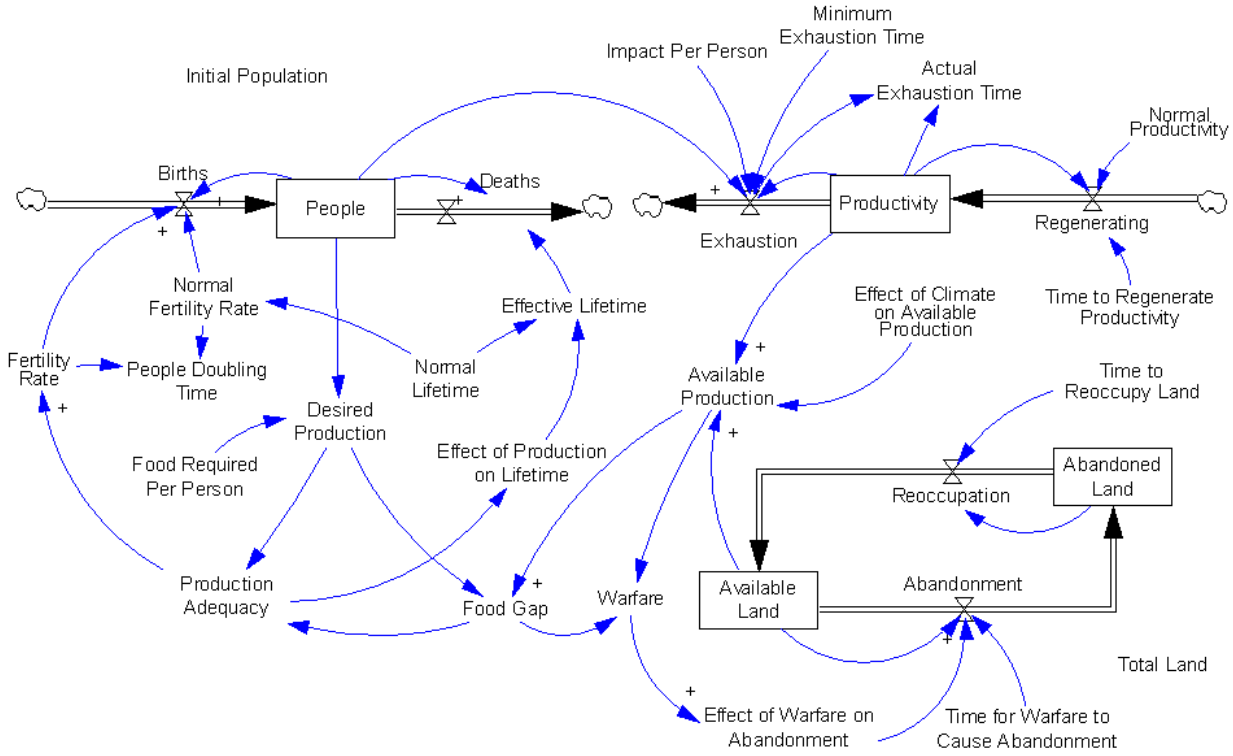
response to resource shortages. In *Beyond the Limits* (Meadows *et al.,* 1993) the authors say that Jay Forrester's World3 model (Forrester 1971) lacks, among other things, war and so is wildly optimistic. This paper is intended to simply and directly temper that optimism.

The Runge paper, hereinafter referred to as *Case Study,* embodies several obsolete concepts. It refers to slash and burn agriculture, which is the prevailing contemporary practice. The Classic Maya, however, used more intensive methods to achieve higher yields and population densities, including raised beds and terraced fields. Runge et al do not include the Late Preclassic sites like Nakbe and Mirador, from before 500 BC, which are comparable in scale and quality to anything that followed. They also overemphasize external trade and foreign contacts: while perhaps seminal at the beginning of the Late Preclassic and Classic phases, the evidence for ongoing political influence is negligible and trade with other citied cultures was light and only in nonessential luxury goods.

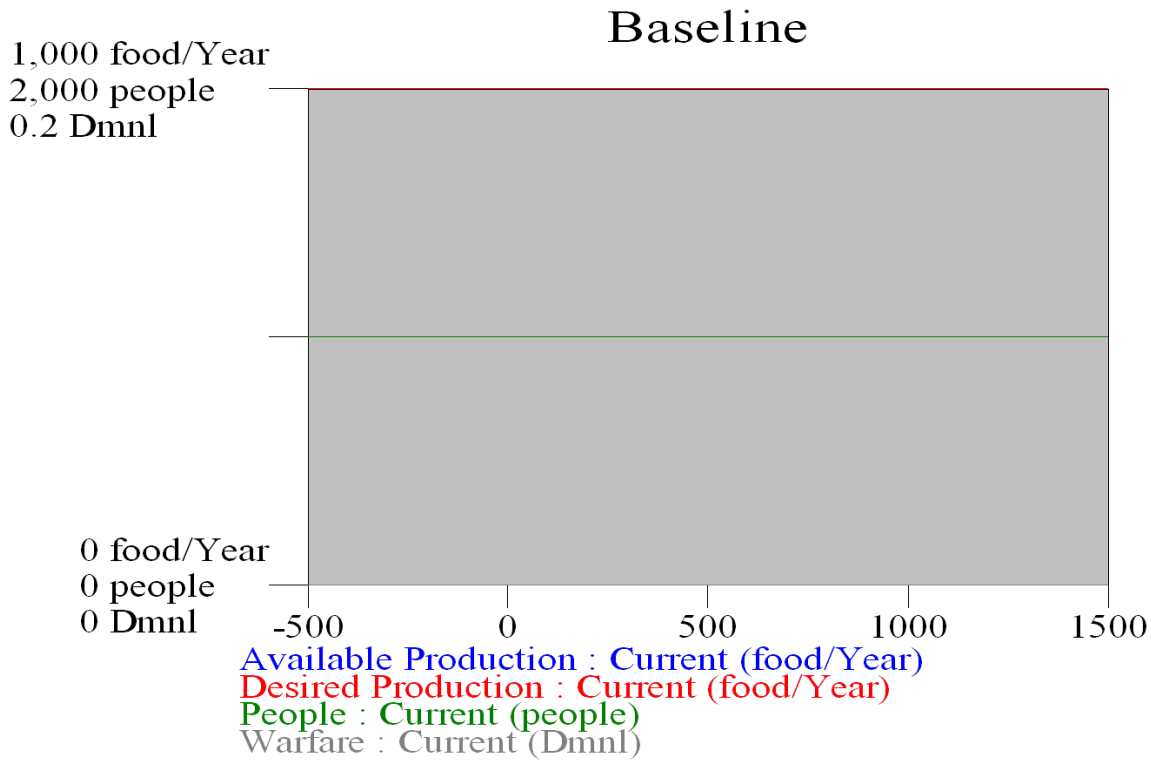
The starting point for the current *Maya Apocalypse* model is *Limits to Growth* (Meadows *et al.*, 1972 New York: Universe Books), with population growing exponentially until it approaches the carrying capacity–which the population is simultaneously eroding. Population spikes, then declines exponentially in line with available production. *Maya Apocalypse* has just two sectors: people and land. Population is increased by births and decreased by deaths. Fertility is high enough to cause exponential growth when production is adequate, and falls below replacement levels as population exceeds carrying capacity, eventually falling all the way to zero. Deaths are regulated through a normal lifetime, which in turn is affected by production adequacy.

Model Description and Simulation Results

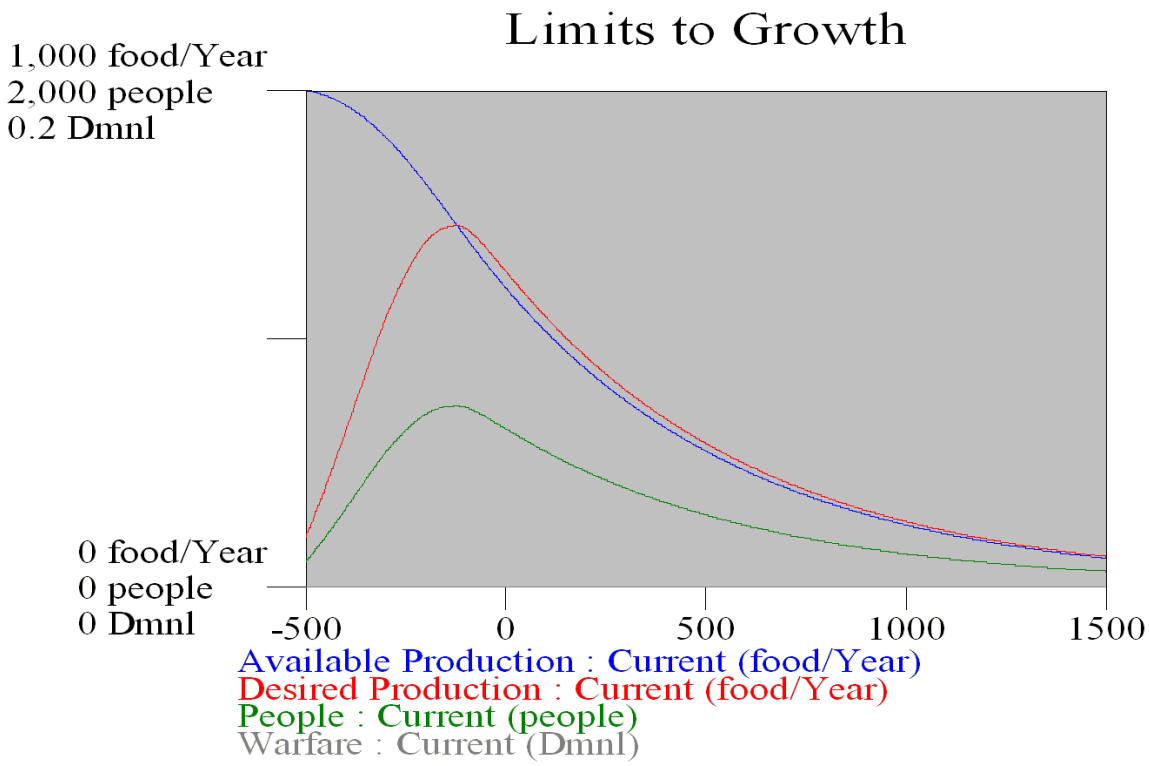
In the current model, the land sector has two variables. One is productivity, which is exhausted by people but regenerates over a period of time. The other, without a direct analog in the *Limits to Growth* or *Maya Collapse* models, is Available Land. When population exceeds carrying capacity, warfare frequency and intensity increase enough to depopulate land. In the archaeological record this is reflected by the construction of walls around cities and the abandonment of farmlands outside the walls. Some land becomes unsafe to use because of conflict, which then reduces the carrying capacity and intensifies warfare. This is an archetypal death spiral. Land is eventually reoccupied, but more slowly than the abandonment. A population collapse eventually hastens the recovery of productivity, so after the brief but severe collapse growth resumes from a much lower level.



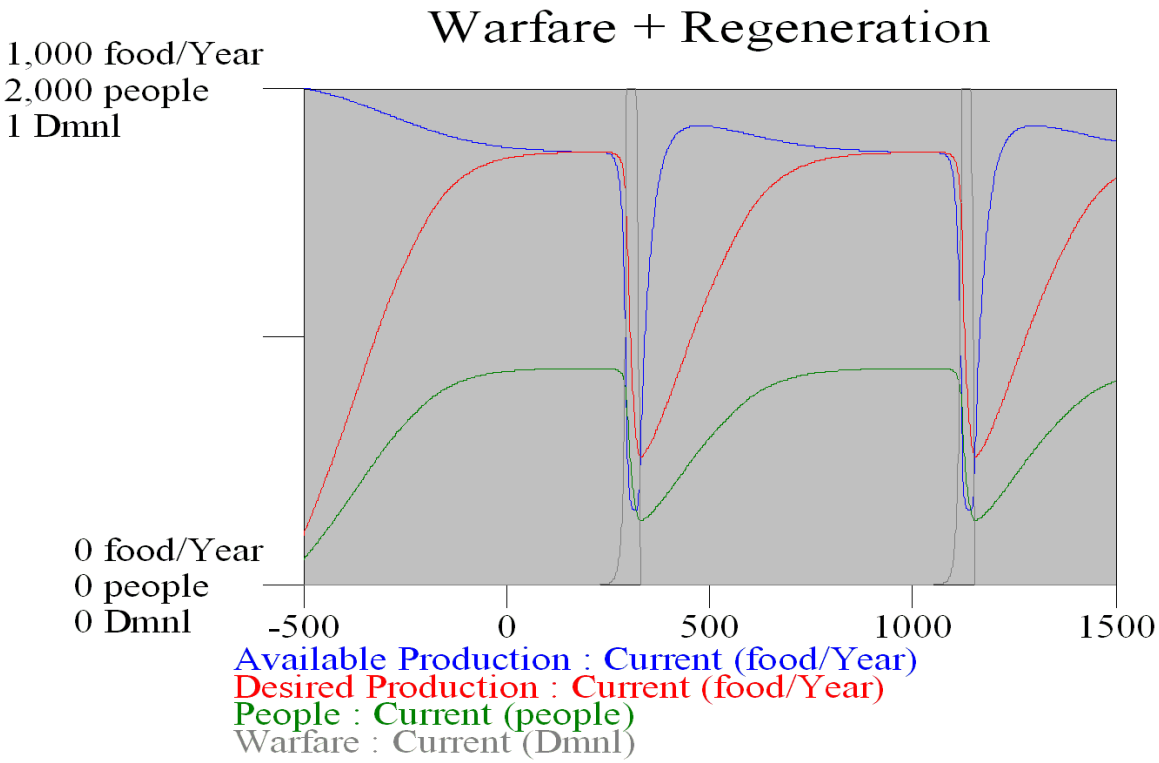
The model has been designed to describe a two millennia period from 500 BC to 1500 AD. Four parameters, with units in years, shape the response of the system: Impact per Person (IP – change in carrying capacity), Time to Regenerate Productivity (TRP), Time for Warfare to Cause Abandonment (TWCA), and Time to Reoccupy Land (TRL). When Time to Reoccupy is zero and Initial Population equals the carrying capacity (Desired Production = Available Production), the systems is in equilibrium and none of the levels change.



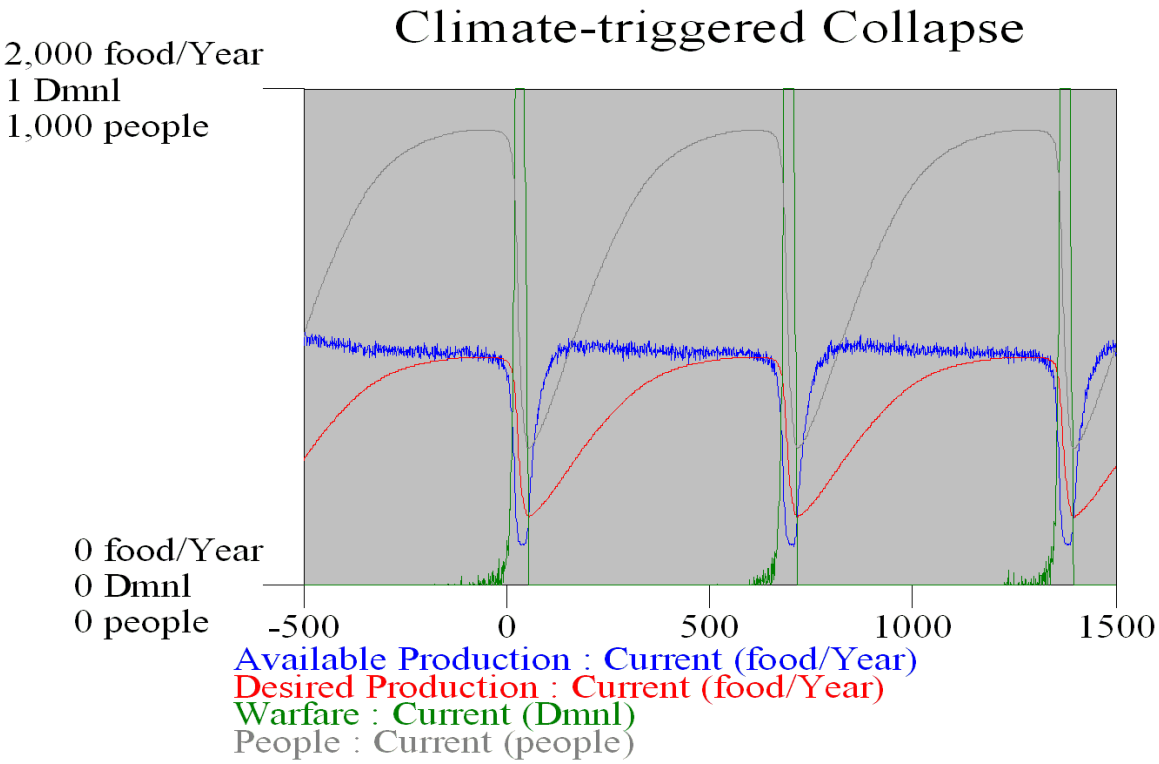
With a nonzero Time to Reoccupy, without regenerating productivity (setting Time to Regenerate Productivity =10^6, which is large enough to make regeneration insignificant), and starting population at 10% of carrying capacity, the *Limits to Growth* mode of exponential growth to a spike followed by exponential decay appears. For this run the abandonment/reoccupation loop has been disabled by setting Time for Warfare to Cause Abandonment to 10^6.



Setting Time to Regenerate Productivity = 100 to enable regeneration, Time for Warfare to Cause Abandonment = 5 and Time to Reoccupy = 25, a sawtooth pattern results: logistic growth approaching a limit, followed by a steep decline, followed by logistic growth approaching a limit, followed by a steep decline... This punctuated equilibrium is the result of asymmetric short-term effects that kick in as long-term stasis is approached. The period of each cycle–the width of each tooth–is about 800 years. The relationship between Time for Warfare to Cause Abandonment and Time to Reoccupy is important to this mode. If the values are reversed, then land is reoccupied as fast as it is abandoned, and available land never gets far from its potential maximum. If the values are close to each other, short-term oscillations result whose damping depends on the exact relationship. But if Time to Reoccupy is at least 3x Time for Warfare to Cause Abandonment, the sawtooth pattern appears: the higher the ratio, the deeper the collapse.



The relationship between Time to Regenerate Productivity and people's normal lifetime (NL=50 in the base case; Normal Fertility is 1/NL) is also important. If Time to Regenerate Productivity < 85, then productivity recovers fast enough to prevent a collapse. With Time to Regenerate Productivity = 100, if NL >63 a collapse is also prevented. Adding an Effect of Climate on Available Production, using the Random Normal function, makes the system much less sensitive to Time to Regenerate Productivity: population collapses for any value of Time to Regenerate Productivity. Indeed, environmental degradation is not needed at all to simulate the reference mode: climate variation can trigger apocalyptic warfare all by itself. The story begins to sound like Murder on the Orient Express, where everyone stabbed the deceased, but the mystery is who delivered the fatal blow? That cannot be answered with the current information at hand.



The key dynamic is that people do not account for the future impact of their numbers on productivity, and therefore production, when they have children. Nor does death by malnutrition and starvation have an immediate effect. This leads to an overshoot, as in the *Limits to Growth*, but the policy response is warfare proportionate to the shortfall, which takes more land out of production and worsens the shortfall.

Put another way, in the growth phase people are in a positive-sum game. There is more to go around, more wealth to share, and population increase is unhindered by policy or production. But once the limits are reached, people are in a zero-sum game, or even slightly negative-sum. Rather than share the pain, people turn on each other to increase their personal share of a shrinking pie at the expense of others. The unintended consequence–the fatal irony–is that by doing so, the pie shrinks much faster than it would otherwise. Apocalypse is the result.

This dynamic has been repeated worldwide, in East Asia, West Asia, South Asia, Africa, and Europe. But in most cases there has been an additional complication, when weakening has proceeded far enough, of a civilization's neighbor delivering the coup de grâce. Late Classic Western Europe, Al-Andalus, Han (and T'ang and Ming) China, Ottoman Europe and Byzantine Anatolia all come quickly to mind, but there are many, many others.

Analysis, Inferences and Implications

The current model has been made just complex enough to illustrate and understand the reference mode, and to explore alternative causal explanations. Two parts of *Maya Apocalypse* bear further articulation. One is the change in productivity–its regeneration and exhaustion. It is an aggregate of the agricultural productivity of all land. There do not seem to have been appreciable changes in technology over the chosen time period, so Normal Productivity is a constant, as is Time to Regenerate Productivity. They are fine for this model, but would have to be reformulated as variables in other settings, and certainly for most of the contemporary world.

Impact per person (on productivity) is a constant, and exhaustion is a simple linear product with population. A disaggregation of Productivity might be indicated if there were different types of exhaustion, or if exhaustion were a nonlinear function of population. But the linear formulation is sufficient for my purposes.

The other model formulation of note is Warfare. Insofar as it affects Abandonment, it has been modeled as a linear function of production shortfalls. As modeled, it has no direct effect on population at all. Certainly there was warfare throughout Maya history, but defensive walls and abandonment were not universal: they were clearly limited in time and space. The destruction and final abandonment of cities were clustered in two brief periods of the 2000 years of Maya history. Those clusters are the primary data for Maya collapse theorists. My theory is that warfare had a negligible effect on the viability of Classic Maya civilization until the carrying capacity was approached, but at that point warfare destroyed it. The language survived. The population survived, though much reduced. But the *k'uhul ajaw* disappeared, and the royal astronomers and chroniclers, the architects, stone masons, and builders became shadows of their former selves.

Two further developments of the current model are worth exploring in subsequent papers. One is that the strongly hierarchical society, with the *k'uhul ajaw* at its apex, was abandoned at the end of the Classic. The post-Classic population curves do not

indicate a population rebounding to previous levels that the current model shows. The post-Classic societies were ruled by *multepal*, so while they were quicker to internal conflict and did not have as large a peace dividend, they also did not fall as hard or have as far to fall in a crisis.

In short, the Classic divine kingdoms created substantial peace dividends, which were destroyed at times of resource scarcity. Demarest (2007) notes a significant increase in minor nobility in the major Maya centers, and postulates them as a causal factor in the rise of warfare. More likely, I believe, they are a symptom: in times of expansion there were new settlements in which minor nobility could occupy newly created roles, but when those opportunities were gone they lingered in the capitals. However, Demarest further points out the per capita costs of minor nobility were higher than those of commoners, thus raising the strain on capacity even when population levels were static. Modeling these considerations would require additional structure, for instance effects of political organization on available land, consumption, and impact on productivity, and policy changes after the Classic collapse.

The other additional development would be to disaggregate the model spatially. There were significant regional variations within Maya lands. The Petexbatun region of Guatemala saw particularly violent warfare: the city of Cancuen was abandoned in a day after a siege and never reoccupied (Demarest 2007). As the Petexbatun was depopulated by war, its people moved to other regions, straining resources elsewhere and starting a cascade of local collapses that played out over several decades.

An unresolved question in my mind is: Why were the abandoned Maya lands not reoccupied, even generations after the collapse of Classic Maya civilization? Demarest (op. cit.) says that Maya politics were much more sophisticated than its economy. The main cities had been built near major portages, but absent beasts of burden and roads, economic activity was extremely local. What wasn't local was small in size or volume, like obsidian, conch shells, and jade. Post-collapse, population recovered quickly near the coast. The Mexican economic model of distributed production created more incentives along the coast and a better quality of life than the economy of the Preclassic and Classic Maya, which Demarest (op. cit.) calls archaic. He likens the collapse of their command economies to that of the Soviet Union. Postclassic cities like Chichen Itza, Mayapan, and Tulum were products of this new economic model, and politically were not as rigidly hierarchical as their predecessors. Demarest (op. cit.) further cites the economic failures of the Peten since 1950 as a counterfactual example of why the Maya lands were not reoccupied, given the difficulties of integrating the area profitably and sustainably into a world economy driven by comparative advantages and specialization.

For the Maya, there were no peace treaties. There were wars, battles, and surrenders. There were superpowers and client states. But once an enemy was made, there was no reconciliation, no nation building, and no exit. Warfare was a death embrace, however many *k'atuns* (Maya 20-year periods) it might take.

Conclusion

Quoting Demarest (2004, p. 296): "[T]he study of the ancient Maya is fascinating precisely because their civilization appears to be so different from our own. The structure of ecological adaptations, settlement patterns, and political and economic institutions could not be more unlike the Western, Mesopotamian, and Judeo-Christian tradition of our own civilization. For at least 6000 years, the hallmarks of the Western tradition have been linear concepts of time, monocultural agricultural systems, overproduction and exchange of surplus in full market economies, technology-driven development, a long history of attempts to separate religious and political authority, and judgmental gods concerned with individual, personal moral conduct. As we learn from the Maya, none of these traits is universal, none of them was characteristic of Classic Maya civilization, and none of them is critical to the florescence of high civilization."

Yet the differences were not total. Other traits were shared even after millennia of divergence, like a violent response to shortages. *Limits to Growth* was a great and influential book that has fostered much necessary thought, discussion, and action. But it's suggestive of a Far Side cartoon with one fly in a sealed jar looking up, startled, and saying to its many companions busily eating honey, "Hey, we're in a jar!" *Limits to Growth* is too optimistic. Paraphrasing John Sterman in *Business Dynamics* (Sterman 2000), all models are wrong, but they can be right enough to make their point, which *Limits to Growth* did. The most glaring omission is of politics and the patron/client relationships at their heart–hence this paper. There is no constituency for lowering the growth in energy usage, much less for lowering energy usage. The world as a whole is in a situation strongly analogous to the Classic Maya. We are playing a positive-sum game. Whether it continues for a *k'atun*, *b'ak'tun* (394 years), or *p'ik'tun* (7,885 years), we cannot say, though the *b'ak'tun* seems an outside number and a *k'atun* an inside number. But we live in a world of divine nations, where growth is God and we build more shrines every day. When we approach our limits, will we walk in the steps of the Classic Maya, and turn our collective pain into global apocalypse?

Structure 1, Calakmul, Campeche, Mexico – Feb. 2006

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