LAND MANAGEMENT: MODELING DEFORESTATION AND DESERTIFICATION IN ORIENTE PROVINCE, CUBA

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This paper presents a preliminary "thought" model of the putative causes of ecological change and desertification of Cuba's eastern provinces (Las Tunas, Granma, Holguín, Santiago de Cuba and Guantánamo), once known collectively as Oriente Province. In particular, the paper refers to a very large part of eastern Cuba, in Oriente Province, comprised mainly of the Cauto River Basin and surrounding mountains (see Encarta map). Other significant river systems, such as the Toa (e.g., Encarta; Díaz-Briquets and Pérez-López, 1993), can be seen, in first approximation, as adjacent repeating satellite subunits.

Here we also consider post-Castro remedies for seriously and anthrogenically[1] altered Cuban ecology which is pushing the Island's climate towards desertification. For this reason, the intent here is to present a thought model to test by future experimental verification through subsequent ecological remediation.

In this paper geological, pluvial, and past and present ecological conditions of Oriente, are discussed as they relate to the biophysical aspects of vegetation evaporation and climate. These factors, plus anthrogenic changes, are interrelated to the process of desertification underway in the region. The model can account for the historic change in climate and rationally attribute this change to removal of vegetation and subsequent erosion and the interruption of ground water flow through dam construction. The model further attributes a major role to loss of atmospheric humidity and thus rainfall due to the collapse of the ecological systems of soil water storage, evapotranspiration, and possibly savanna hydraulic lifting that have multiply effects on precipitation by recycling water. The model has apparent common principles to economic theories where in the continuous recycling of "wealth" by multiple complex commercial interactions is fundamental to a sound economy.

PRESENT CIRCUMSTANCES

The Cuban government's vast and widespread land mismanagement has led to a severe ecological crisis, with desertification appearing and spreading (e.g., Wotzkow, 1998; Díaz-Briquets and Pérez-López, 2000) and entire species of plants being lost or already lost (e.g., Méndez Santos, 1997). The Cuban government adroitly dodges the blame for desertification (e.g., Pagés, 2004a), illogically attributing the problem for such increases in available water vapor to "Atlantic warming." Officially now, "There are no major rivers in Cuba" (UNCCD, 2003). Apparently, the once navigable Cauto, where essentially every tributary is now dammed, no longer qualifies, and the Toa River (see Marrero. 1981, p. 348, fig. 464), is forgotten.

Given the drought situation in eastern Cuba (e.g., Bauzá, 2004; Associated Press, August 7, 2004), where, until recently, in places it had not rained for

1. Anthrogenic effects result from human activities, such as the burning of fossil fuels or deforestation. See for example, http://www.peopleandplanet.net/section.php?section=8&topic=8.

twenty months (Pagés, 2004b), one of the first priorities should be the restoration of the forest vegetation. Even Hurricane Charley, as observed by NASA's spaceborne Atmospheric Infrared Sounder (AIRS) (NASA August 13, 2004), and subsequent hurricanes probably did not help as much as hoped (e.g., Pages, 2004a, b) in present ecological circumstances. Thus, "on August 13, Hurricane Charley … struck western Cuba (Havana province) with sustained winds of 90 to 95 knots (104-109 mph) and gusts of 110 to 115 knots (126-132 mph). Satellite rainfall estimates for western and central Cuba and Jamaica were 100 to 200 mm (4-8 inches), with lesser amounts in eastern Cuba (50-100 mm, 2-8 inches) (USDA, 2004)." And on September 2, 2004, only 30-40% chance of rain was reported for Holguín as hurricane Frances passed relatively close to the north (Excite weather 9/2/04). It would seem that the mountains (Nipe-Sagua-Baracoa complex), to the north and east, blocked most rain from reaching Holguín and the rest of the Cauto watershed.

EVALUATION OF CAUSES

One could most logically suggest that the loss of vegetation has severely decreased the recycling of water by plants, which is the major factor responsible for the climatic change in the Cauto watershed. It seems from present circumstances that agricultural and forestry policies of the Cuban government not only have failed in the past, but because such policies continue, the circumstances have worsened.

The much touted ecology restoration projects of the present government have also failed to make a difference. For example, some ecological remediation work in Cuba has been supported by the United Nations (e.g., Pérez and Gerez, 2002). However, the area remediated is little more than an experimental plot, too small to make even a local difference. Reviewing results of this and similar projects suggests that the present regime in Cuba, even in the present dire situation, is still more interested in the propaganda value than actual scientific work. Therefore, given these particular circumstances, such work needs to be verified by satellite imagery (e.g., Daley, 2001) until regime change permits on-site inspections.

Interactions between vegetation and climate are considerable and complex. Principal factors will first be considered separately, then considered in relation to each other, and in relation to anthrogenic changes. Principal natural factors include: (1) sea temperatures; (2) geological structures; (3) wind speed and direction; (4) rainfall; (5) the flow of the rivers and subterranean waters; and (6) vegetation. Anthrogenic factors include: (1) bureaucracy; (2) dams; and (3) deforestation.

Natural Factors

Sea temperatures are not, despite statements by Pagés (2004a), very amenable to direct anthrogenic change, although some change may be effected by man (e.g., through iron salt additions, see NASA, 2004). Theoretically, "global" warming of the sea will merely promote increased water vapor in the atmosphere and, under appropriate conditions, more rain on land.

Various mountain ranges, principally the Sierra Maestra at the south and the mountains of the Nipe-Sagua-Baracoa complex, circle the province from the east and north. These are, at least for our purposes, the most striking geological structures of Oriente Province. Viewing the mountain ranges from space, they have the form of an arrow head pointing east and this shape extends far out under the sea (NOAA, 2004).

These mountain structures clearly result from the geological evolution of the Caribbean (100 million years ago to the present) in which Cuba drifted in from the Pacific between then-separated North and South America, to collide with the Florida Platform, opening the Cayman Trough (Scotese, 1999). Sixty-five million years ago, the great comet "Chicxulub" hit off the north coast of Yucatan, perhaps less than a thousand miles north and west of Oriente Province, further rumpling the mountains (e.g., Lendroth, 2004).

The mountains in Cuba are somewhat older and lower (the tallest peak Turquino is only 6,400 feet) than the almost 9,000-foot high Pic la Selle in Haiti and the over 10,000-foot Pico Duarte in the Dominican Republic. Jamaica was originally no more than a few meters above sea level from the middle Eocene to the middle Miocene, although subsequent orogenic activity has obliterated part of the widespread limestone formations (cockpit country, karst) that give testimony to this. However, the Blue Mountains of eastern Jamaica, uplifted only 5 to 10 million years ago, now rise to over 7,150 feet (e.g., Blair Hedges, 1996). However, in the Oriente area of Cuba, these mountains, although lower, are quite steep. When these mountains are deforested massive landslides are common and lethal (personal memories 1948-1961; and family accounts).

Winds on the plains can also be modified in intensity and humidity by windbreaks (e.g., Cleugh, 2002; Cleugh and Hughes, 2002). Especially in September and October, winds come north across the Gulf of Guacanayabo (National Geospatial-Intelligence Agency NG-IA(US), p. 64, col. 1), resisting the return of the water vapor to the sea and trapping humid air as clouds over the Cauto plain and adjacent slopes of the mountain ranges.

Rainfall is often heavy (Marrero, 1981, pp. 76-77, Fig. 61; Daley, 1997a). In the Cauto Basin proper and in the rolling plains to the northwest, precipitation is from an inadequate 25 to a sufficient 65 inches a year in modern times as the area has become deforested (Borhidi, 1991, pp. 345-346). Illustrations and comments in the historic literature (e.g., navigation on the Cauto and Bayamo Rivers) suggest that the area was far more humid up at to about the end of the 19th century. Because of vicious depopulation during the long wars of Cuban independence (1968-1898), it was naturally re-forested by secondary growth of "sao" and "manigua."

The flow of rivers (see Encarta site) and subterranean waters have already been strongly modified by dams built by the present Cuban government (Díaz-Briquets and Pérez-López, 1993). Dam building apparently continues (Daley, 2001), and as a result surface and underground water flow continues to be disrupted

Frequently in Oriente, river flow was moderated by the permeable calcareous cap that covers part of the mountains. This cap, formed of cave ridden karst rock, allows percolation of rainwater into slower flowing underground streams. For example, during the dry season, parts of the Guamá and Guisa Rivers (personal observations, 1948-1960) ran mainly underground. This changed when these subsurface karst caverns were sealed off by dams that blocked almost, perhaps all, the rivers in the area: "by 1992, Cuba had 200 dams and close to 800 microdams" (Díaz-Briquets and Pérez-López, 1993; see also Daley, 2001).

Stanford et al. (1996) state:

> ….ecological connectivity between upstream and downstream reaches and between channels, ground waters and floodplains may be severed. Native biodiversity and bioproduction usually are reduced or changed and non-native biota proliferate.

This harms the total ecology. Of particular interest here is the disruption of the recycling of surface and ground water through evapo-transpiration from arboreal vegetation; this is especially important with regard to loss of riverine gallery forests (Daley 2001, 2002 and manuscript in progress).

Vegetation on the plains below and between the mountains, although severely changed by sugarcane growing in the first half of the 20th century, has been even harder hit by the present government's mismanagement during the second half of the century (Wotzkow, 1998). Population growth, combined with reduction of standards of living and diminished sources of fuel, has enhanced the demand for wood to cook food. This tree cutting has not helped the ecosystem.

Cuba was perhaps once 90%-forested with a vast array of tropical trees species (e.g., Borhidi, 1991; Cohen, 1969; Enamorado, 1917; Fors, 1956; Frere Marie-Victorin and Frere Leon, 1942-1944; Marrero, 1981; Maza Jiménez and Roig y Mesa, 1914; de la Sagra, 1843; Seifritz, 1943). Cattle, and thus pastures, were a major part of the economy after the Spanish conquest (e.g. Marrero, 1981).

Due to the mechanisms of transpiration, necessary for inorganic transport and photosynthesis, plants recover and re-emit to the air considerable amounts of water vapor (e.g., Tesar et al., 1992). At most, 2% of the water is split and used biochemically to provide "hydrogen-reducing power." Thus, essentially all the water is taken up and evaporated and thus cools the area around the plant, shrub, or tree. This process of cooling is less in pastures than in forests, because cutting down forest to develop pastures influences climate unfavorably (e.g., Grace and Malhi, 1999).

My memories of the Cauto Plain, even in late 1958 (Daley, in preparation) include abundant large trees scattered in the pastures, along the water courses, and in and around swamps. These factors significantly influenced military action even close to the central highway. What one sees of that area in present day travel videos seems to indicate that all or most of these trees are gone.

Early in the colonial period, prior to serious sugar production, capturing feral cattle was a principal source of exchange (e.g. Esquemeling, 1678). In 1782, George, Lord Rodney (1932, volume 1, p. 313) reports "collecting" 30,000 bullocks near Guantánamo Bay (he called it Cumberland); this would be an amazing concentration of cattle for the dry conditions found there today. The successful slave revolt in Haiti (1790-1804) brought coffee growing to Cuba's forested mountains (Marrero, 1981 pp. 187-188). Hurricanes diminished production by 1850, and war allowed reforestation (Marrero, 1981: Enamorado, 1917). Coffee culture returned by mid 20th century (Daley, submitted).

Although there is "no tradition that it ever occurred in the province of Oriente," the presence of Cuban macaws (*Ara tricolor*, Forshaw and Cooper, 1977, pp. 366-367) is probable since the Taíno term for the bird *guacamayo* (Zayas, 1914) is still in use throughout the Spanish speaking Caribbean. Thus it is interesting that in about 1864 (four years before the Ten Years' War) this long-lived bird, often semi-domesticated as a watch animal and a food source, disappeared (Forshaw and Cooper, 1977). We could consider this extinct bird (which may be returned to existence through bioengineering of still extant related species in South America) to be a marker for wilderness and a final crowning touch to a successful ecological restoration.

Anthrogenic Factors

Dams can make matters even worse in tropical islands. March et al. (2003) state: "The combination of human population growth, increased water usage, and limited groundwater resources often leads to extensive damming of rivers and streams on tropical islands. Ecological effects of dams on tropical islands can be dramatic."

The Cuban bureaucracy avoids blame for removal of vegetation and praises the river dams that have helped cause the droughts (e.g., National Watershed Council, 2004). However, even some Cuban government organizations have been forced to admit such harm, while stating that recently things are changing for the better (e.g., Cuza Pedrera and Milan Verdecia, 2004).

Deforestation apparently to sell valuable timber continues according to rumor in the Sierra Maestra which is a military and thus closely guarded zone. It would be appropriate to check this with high resolution, e.g., 20 cm, resolution satellite scans.

THOUGHT MODEL

The model is simple, thus it should be readily tested against reality. In this construct we view the matter of desertification in physical, hydraulic, and biophysical terms. The warm seas are sources of water vapor, and the higher, and thus colder, mountains are condensers (Marrero, 1981, p. 69). We view the matter simply, with water vapor turning to rain and falling on the mountains to form rivers. The rivers flow from the mountains crossing the plains both above and below ground, towards the sea. When the mountains are forested, flow rates are slower, but more continuous (e.g., Heartsill-Scalley and Aide 2003). When the hills are bare, the rivers become great torrents, and then dry to trickles.

The mountains intercept clouds from the sea and gather rain for the land. Yet, the surface characteristics of mountains can be drastically modified by anthrogenic deforestation, which contributes to climate change. Denuded mountains do not hold water, causing mountain-ripping floods, similar to the recent horror in the mountains between Haiti and the Dominican Republic. Since the water is released rapidly and rushes back to the sea, in times between floods there are droughts (e.g., Reuters, 2004). Deforestation is a problem ultimately attributed to bad government.

Widespread deforestation promotes a warmer and drier climate. By some estimates (e.g., Zhang and Henderson-Sellers, 2001), deforestation reduces precipitation by as much as a foot of rain a year in Amazonia, apparently by decreasing water recycling through transpiration and plant hydraulic lifting. Thus, recycling transpired water is of the utmost importance. Hydraulic lifting is the term given to the elevation of water by plants such as savanna trees from deeper levels. Hydraulic lifting, apparently more usual in savannas than forests, is another factor under intense investigation (e.g. Moreira et al., 2003; Ludwig et al., 2003; Archer et al., 2002; Jackson et al., 1999). This water is in variable degree shared by shallower rooted species.

Gallery forests (Daley 2001, 2002, manuscript in progress) which recycle river water into the atmosphere can be adversely affected by dams (Rood et al., 1995; Rowland et al., 2001; Obedzinski et al, 2001), although the effect can be, and probably usually is, species dependent (Horton et al., 2001; Rowland et al., 2001).

Windbreaks, restoration of the gallery forest along the rivers (Daley 2002), and the replacement of felled pasture trees, may help climate control, but given the damage done already, this may not be easy in Cuba. Yet, we presume by the relative novelty of the events in the area, that almost irreversible Sahel-like conditions (e.g. Hess, 1998) do not yet exist. Thus, increasing plant mediated water recycling by reforestation will aid the restoration this once incredible fertile area (Cohen, 1969) to less arid conditions with somewhat lower temperatures.

CONCLUSION

A simplified thought model is used to describe the circumstances of climate and rainfall in Oriente Province, Cuba. This model can account for the changes in climate and subsequent desertification. The main hypothesis that loss of forest is a major cause of desertification is not a novel one, but is profoundly significant. The model provides testable hypotheses for remediation that could serve as basis for experimental work in the post-Castro Period.

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