RESTORATION OF CUBAN GALLERY FORESTS, ESPECIALLY ON THE BANKS OF THE BAYAMO AND OTHER RIVERS OF THE CAUTO BASIN

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Cuba was once a land of complex forests, and these forests were a foundation of much prosperity. Not only were precious woods logged for export, but natural products, such as dye-woods, were sold as well. For example, some of the natural medicines listed in Parke, Davis & Co. manuals (1890) surely came from Cuba. However, the forests of Cuba have dwindled, and their loss is not only esthetic and environmental, but economic and climatic as well.

In the Cuba of the past century, reforestation has not been easy, and mostly unsuccessful. Given its forty plus years in power, and absolute authority, a large proportion of responsibility for these failures can be laid at the feet of the present Cuban government. As this government reaches towards its end, fossil fuel has become scarce, and demand for firewood for cooking has done critical damage to the forest environment. After all is over, restoration of the complex original forest of Cuba will be even more urgent but not much easier, since deforestation itself gives place to undesirable, difficult to reverse, climate change. Therefore, the approaches to be considered here are cautious and long term.

The intent here is to develop plans to restore one critical part of these forests: the gallery forests that once lined the streams and rivers of Cuba. Specifically this paper addresses the circumstances of the Cauto River watershed in eastern Cuba, with emphasis on restoration of the gallery forest on the now denuded banks of the Bayamo river.

One principal reason for this objective is that forests at the edges of waterways reduce air and river temperature. Those who know Cuba recall the chill of entry into these forests, living climate regulators, which evoked in the ancient Taínos the legend of the Jigüe, the water sprite. More importantly recent studies show that loss of forest severely affects climate. Approaches suggested are diverse. The important consideration is that multiple methods be tested. Then experimental results, not *dictat* by political superiors, will determine which are used.

CUBA'S RIVERSIDE GALLERY FORESTS

Borhidi (1991 p. 446, common names from Victorin and Leon, 1944; Fors, 1955; Mabberley, 1993) describes "riverside gallery forests" thus:

> the gallery forests along rivers and creeks are rich in lianes, palms and tall grasses and have only a single canopy layer. Characteristic elements are *Roystonea regia* (royal palm), *Calyptronoma dulcis* (manaca palm), *Lonchocarpus domingenesis* (guamá), *Lysiloma bahamense* (abey, bahama sabicú), *Dalbergia* (palo de rosa) *Ecastophyllum, Bucida buceras* (júcaro), G*inoria americana;* of the lianes *Arthrostylidium cubensis* and *A. capillifolium*, and of and of the tall grasses G*ynerium sagittatum*, the latter forming dense stands like reeds.

One should note that in Cuba speciation to the islands very diverse habitats is common. For example, there are perhaps six species of royal palm (Zona, 1991). Often selection of habitat is a strong influence (e.g. Zona, 2002).

Naturally there are many other gallery forest species. Victorin and Leon (1944 p. 175-178) mention some when exploring the areas north of the Zapata swamp, in a hidden ravine near the Hanábana river. There associated with manaca palms, they found C*hrysophyllum oliviforme* (caimitillo), *Hisbiscus elatus* (majagua), the skin slicing tibisi vine *(Lasiacis divaricata),* and *Smilax domingensis* (alambrillo). Nearby these authors also described huge C*eiba pentandra* (ceiba) and *Hura crepitans* (salvadera) trees

The rationale for this objective is that reforestation at river edges keeps river temperature and thus evaporation rate lower, aquatic life preserved, valuable plant diversity saved, erosion reduced, and disastrous flooding ameliorated. The harmful effects of deforestation on tropical climate are well established (*e.g.* Shukla, *et al.* 1990; Nobre, *et al.*, 1991; Zheng and Eltahir 1998)

Cuba was 90 % or more forest at the time of European contact (*e.g.* Casas circa 1474-1566) and fever and war maintained these areas largely intact through the 19th century (Marti, 1895; Enamorado, 1917). Large forests still existed at the start of the 20th century (Wilcox, 1908, 1924); and in mountainous areas until the 1940s and 1950s (*e.g.* illustrations in Woodring and Davies, 1944; Marrero, 1981).

The Cuban paradise with abundant fruit, medicinal and other useful trees, that Columbus found was due in part to the fact that, unperceived by the arriving visitors, a certain amount of the forest was in semi-cultivation. Only now is this seen as being a version of a pre-Colombian, Mayan practice.

First, it is recognized that reforestation has not been easy, and mostly unsuccessful in Cuba. A large proportion of the responsibility for these failures can be laid at the feet of the present Cuban government (Díaz-Briquets and Pérez-López, 2000).

However, the political problem is only one of the many barriers to reforestation. Restoration of the complex original forest of Cuba will not easy; thus, the approaches considered here are long-term.

Increasing the dangers of flooding rivers are the massive dams built in the last forty years; if press reports are true some of these have already failed. The area of interest has a history of severe earthquakes (Daley, 2001) documented by successive church collapses (Ortega Alvarez, 1999). The idea of a river pouring through a broken dam and then going down stream, churning deadly mud between and above unprotected riverbanks is terrifying.

Arguments that riverbank deforestation reduces tree evapo-transpiration and thus increases stream flow are not considered applicable to the circumstances of mountain girt Oriente province (National Geophysical Data Center). The reasons for this is that evapo-transpired water vapors blowing towards to the north east and south re-condense as against the mountains making additional rainfall, and consequent stream flow. To the west is the water-saturated air of a humid shallow sea (National Geophysical Data Center).

Thus, the circumstance of Cuba is similar to Amazonian, Asian, and some Africa forests where a great deal of transpiration ends up again as rain (*e.g.* Nobre *et al.*, 1991). Without sufficient evapo-transpiration from trees, less water recycles and rainfall diminishes (Sukla, *et al.*, 1990; Nobre, *et al.*, 1991; Zheng and Eltahir, 1998; Otsama, 2000), as was readily deduced by José Martí more than a century ago.

CUBAN GALLERY FOREST RESTORATION

The primary question is how to reforest, since it is not simply a matter of replanting trees of climax species. Deforestation harms the soil and the total ecology, and ushers in climate changes; this makes it difficult for climax species to thrive (*e.g.* Thompson *et al.*, 1992). Thus, there is need for more tolerant transitional species. Luckily, trees grow fast in Cuba, and the centuries required for establishment of climax forest in places such as Oregon are much shortened on this tropical isle.

Fire—a great problem in Oregon—is far less likely in the gallery forests (Cuban pine forests are in different areas) of Cuba. Kellman and Meave (1997), working in Belize, state "the outer boundaries of gallery forests are fire-prone zones, but fires rarely protrude into the these forests." Ratter *et al.* (1997) makes similar remarks about the Brazilian Cerrado.

In Cuba, following Asian examples (Otsama, 2000), it would be prudent to take care when gallery forests are adjacent to guinea grass (P*anicum maxima*) pastures where fire is used to control brush. Fire tolerance is attributed in Belize to trees such as S*ymphonia globulifera, Vochysia hondurensis,* and *Matabaya oppositifolia* in the outer zone of the gallery. The first two are not known to be present on the island. However, the Cuban flora contains M*atabaya oppositifolia* (macurije)*, M. apetala*, and M. *domingensis* (Zayas, 1914; Fors, 1955; Borhide, 1991). Macurije, a medicinal tree, has given its name to several places on the Island (Zayas, 1914)

Cuba is a tropical (semitropical for purists) island with a wide variety of soils, with varied terrain and rainfall (*e.g.* Borhidi, 1991). The panoply of Cuban tree species is amazing (de la Maza *et al.,* 1914; Victorin and Leon, 1944; Fors, 1955; Alain, 1962; Borhidi, 1991, Daley, 2000, 2001, Areces-Mallea, *et al.* 2001). Thus, the approaches suggested are similarly diverse.

The role of insects such as ants in protecting of trees (Rickson, 1977; Rickson and Rickson, 1986, 1990) and the feeding attacks of other invertebrates (*e.g.* Hochmut, 1982; Nascimento and Hay 1994) must also be taken into account. To reduce the spread of plant pathologies, mixed tree stands containing many different species are most appropriate.

One approach is to start at "ground zero" with a transitional forest, using rapid growing native weed tree species such as guava (P*sidium guajava*), ateje (C*ordia colocca*), yagruma (C*ecropia peltata*), and algarrobo (*Samanea saman*). However, even these weed species have habitat preferences. Once established these transitional forests, planting with longer-term shade tolerant climax species can be done.

For riverbank protection, the otherwise troubling invasive system of tangled vines and other undergrowth, commonly called *sao*, *o*ffers some positive features. Thus, use of vines (lianes) should be considered.

Another approach is trying to take advantage of proven invasive non-native species such as pomarosa (rose apple, S*yzgium jambos,* formerly *Eugenia jambos*) and sour orange (C*itrus aurantium*). The pomarosa whose massive reclining dark trunks, and fragrant floating yellow fruit were once common at the edges of the most rivers of Cuba could also be repropagated and re-introduced. The majestic wild mango trees (M*angifera indica*) once ubiquitous in the Cuban countryside and the curved elegant coconut palms (C*ocos nucifera*) may also prove useful. The germplasm selected, for all species used for these purposes, should be as variable and disease resistant as possible.

The diversity of the forests of Cuba is a product, not only of natural processes, but also attributable to thousands of years of human habitation, and importantly incipient speciation of introduced arrivals.

Here purity of ecological thought should be moderated since although Cuba has a large number of endogenous plant species (*e.g.* Borhidi, 1991; Daley, 2000), many other species were introduced both prior to the Spanish arrival and afterwards. For instance Cuba shares some traditional food (Galinat, 1971) and medicinal plants (Robineau, 1990) not only with other Caribbean islands (*e.g.* Little and Wadsworth, 1964), but also at the level of genera and even species, with Central American and Amazonia flora (*e.g.* Schultes and Raffauf, 1990). Since, the Island was a terminus for Taíno migrations from, or through, these areas (Rouse, 1992), human transport seems most probable.

It is not correct to view the alarming acceleration of the spread (recent press reports) of marabú (*Dichrostachys nutans* (*Cailliea glomerata*)) thorn forest (Victorin and Leon, 1944) as a common consequence of plant introduction. Marabú is an exception, which even has good points, such as enriching the soil with nitrogen (Allen and Allen, 1981). Other leguminous trees in Cuba also do this (Rodríguez, *et al.* 1984). Thus, the rumored inclusion of marabú thicket acreage in "enhanced" reforestation reports by the present Cuban government, although amusing, is not without some small merit.

Associated Biofactors for Sustained Reforestation

It is not enough just to reforest; such forests must return to a self-sustaining condition. Pollination, and seed dispersion which commonly involves birds, bats and other vertebrates as well as invertebrates, are fairly well understood (*e.g.* Hovestadt, *et al.* 1999). This is also true for many folivorous (leaf eating) insects and plant pathogens (*e.g.* Hochmut, 1982; Nascimento and Hay, 1994).

The forests of Cuba sustain a varied wild life, mainly birds (Garrido and Kirkconnel, 2000), amphibians, reptiles (Sepland and Schwartz, 1974; Estrada and Hedges, 1996; Rodriguez Schettino *et al,* 1999), and invertebrates (e.g. Martínez and Sánchez, 2002). Most are familiar with the need for old growth trees to provide such things as nesting holes (often in old palms) to support such birds as the Cuban parrot *Amazona leucocephala palmarum* (Forshaw and Cooper, 1977) However, there are a few strange mammals such as the—perhaps, or perhaps not, extinct—poison-fanged almiquí or *Solenodon* (Barbour, 1944; Walker, *et al.,* 1964; Ottenwalder, 1985,1991; Dufton, 1992). The wild dingo-like dogs apparently came with very early settlers perhaps with the "mammoth hunters" who preceded the Taínos (Rouse, 1992; Schwartz, 1997).

All these animals interact with the vegetation of the forest, where much of the nitrogen in the soil most probably is fixed by leguminosae trees. The rich ecology and variability of Cuban woodlands is demonstrated by the number of such legume trees. These trees include: Abey (*Lysiloma bahamensis*), Abey Blanco, Azul de sabana or Azulito, encinillo, and menudo (*Pithecellobium berterianum, P. obvale, P. discolo, P. arboreum, P. dulce* (Inga, Guamuchil), *P. glaucum, P. hystrix, P. lentiscifolium, P. nipense, P. oppositifolia, P. prehensile*), Algarrobo (*Albizzia (Samanea) saman*), Bacona (*Albizzia cubana*), Brasil, Brasilete and Guaracabuya (*Caesalpinia vesicara, C. rugeliana, C. Bonduc, C. glandulosa, C. moanensis, C. nipensis, C. pauciflora, C. pinnata, C. subglauca, C. vesicaria, C. violacea* and *C. coriaria*), Cañadonga (*Cassia grandis*) and relatives (*Cassia Bucherae, C. chrysocarpa, C. diphylla, C. Ekmaniana* (Guacamaya), *C. emarginata, C. indecora, C. ligustrina, C. lineata, C. minutiflora, C. nova, C. pilosa, C. rotundifolia, C. scleroxyla, C. Shaferi, C. stenophylla,* and *C. turquini*), Granadillo (*Byra ebenu, B. serrulatum, B. Tuerckheimii*), Guabá (*Inga vera*), Guamá (*Lonchocarpus domingensis, L. longpipes, L. pentaphyllus, L. sericeus*), Guamá candelón and relatives (*Piscidia piscipula, P. cubensis, P. havanensis, P. crenata, P. Forsythiana, P. hemisphaerica, P. intermedia, P. lurida, P. mayarensis, P. micromeriaefolia, P. microphylla, P. moaensis, P. obtusangula, P. pumileoides, P. repens, P. simplex, P. spathulata, P. trianthemoides, P. uninerva*), Guacancillo (*Behaimia cubensis*), Jurabaina (*Hebestogma cubensis*), Orejas (*Enterolobium cyclocarpum*), Palo de Campeche or Blood wood tree (*Haematoxylon campechianum*), Pico de Gallo (*Tounatia (Swartzia) cubensis*) (*Cynometra cubensis*), Caguairán or Quiebra hacha (*Guibourtia (Pseudocopaiva) hymenaefolia*), Sabicú (*Lysiloma latisiliqua*), Tengue (*Poeppigia procera*), Yaba (*Andira inermis*), Yamagüey de Sabana (*Belairia mucronata*, *B. parvifolia, B. spinosa, B. ternata*), Yarúa (*Peltophorum brasiliensis, P. aldnatum*) (Fors, 1956; Allen and Allen, 1981; Borhidi, 1991; Mabberley, 1993).

When one sees the many colorful butterflies of Cuba, one should realize that many of their caterpillars eat tree leaves (Schwartz and Hedges, 1991; Silva Lee, 1996; Johnson and Coats, 1999). Less clearly realized is how trees are associated with fungal endophytes (*e.g.* Hoffman, *et al.* 1998; Daley, 2000); and how trees rely on the protection or nutrition supply mediated by invertebrates such as ants (Rickson, 1997; Rickson and Rickson 1986, 1998). Even the once dreaded land crabs of Cuba may play a role, as do other crabs in Ecuador (Twilley *et al.* 1997).

Background Information

To know what is unknown is as important as it is to know what is known. There is considerable information available on the botany of tree flora of Cuba, a general compilation of germination and growth rates. There are even thorough works on the associations of tree flora with soil type, location and rainfall (Borhidi, 1991). What seems missing are complete bodies of work, compendiums, covering disease resistance, nutritional, and light requirements, interaction with associated fauna and flora, etc., for all or most of the trees of Cuba. Thus, further basic research must be done to support of any project of this nature

Manpower

There are a good number of forestry scientists now in Cuba, who must make a transition from poorly paid protected status, to life as scientists in the real world. The personal trauma and waste of such scientific skills in the change to new conditions, common circumstances in Eastern Europe, could be ameliorated by such projects. These research projects, would also help give these scientist the pertinent experience, and time—with food on the table—to thus allow them to more readily adapt to a more competitive free enterprise environment.

External Support

If U.S. funding becomes available after the present circumstances in Cuba end, it will be important to set up extension and other support on the efficient applied us model (Daley, 1999).

Material and Methods

Imagery and Associated methods are described in Daley (2001)

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