Bamboo boosted Historic Climate Change

Jörg Stamm, February 2004

This paper presents a focus on the forestry part of the interdisciplinary investigation recently presented by Franz Faust[1], Hermann Mannstein[2], Cristobal Gnecco[3] and Jorg Stamm[4].

Abstract:

*The essay links several investigations of pre-industrial human impact on climate and draws conclusions for actual CO_2 fixing efforts. As special focus it outlines the example of the extraordinary capacity for biomass fixation by the American bamboo "*Guadua angustifolia*", and estimates its historical contribution to the rapid climate change (second wave of the "Little Ice Age": 1550 to 1850). Guadua as pioneer in secondary forests acted in the past as significant CO_2 sump, which ocurred by natural reforestation in consequence to the catastrophic native population decrease, enabled by the lack of imunity to several epidemic deseases during the 16th century all over the new continent.*

Guadua clumps are for the first time described in its potential as a pioneer plant and as a reforestation booster, especially as the key element in preparation of soil and water management for natural succession of endemic trees. Its anatomical and physiological qualities are outlined and placed into a symbiotic function of tropical rainforest recovery after natural or anthropogenic impact.

Most of the data is based on forestry studies about "guadua" stands in what is now called the "coffee region of Colombia", which was in early colonial times the home to the Quimbaya, who cultivated "guadua" as one of their essential resources for tools and housing. The plant's average potential of 9 tons/ha/year of carbon sump in tropical South America is linked to 300 years of lack of land use and natural reforestation. The population decrease is shown by evaluation of colonial archives of tax contributions of the Quimbaya region. Former land use per capita is estimated and cross-referenced with anthropological data, to approach potential areas of natural reforestation over the Americas.

Pan - American forests, now covering probably 50 - 100 million hectares of formerly cultivated land by Amerindians before extinction, estimating a quick carbon accumulation in secondary forest of 100 tons per hectare, could justify a considerable carbon sump of more than 10 billion tons from the world's atmosphere, responsable of lowering the average world temperature about 0,1 to 0,2 degrees, like described by climatologist Hermann Mannstein.

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Introduction

When Botanist Alexander von Humboldt traveled through Colombia in 1801, he described the extraordinary abundance of bamboo forests in the Cauca River Valley, but he also investigated the same plant at the remote Casiquirae River in the Amazon / Orinoco riverbasin. Initially called "Bambusa Guadua"- a "cane, as thick as mans leg" (the proper taxonomy is in 1826 determined "*Guadua angustifolia*" by his partner Kunth), Humboldt described this giant bamboo species as dominant but "social" plant in the forest comunity. This woody tropical bamboo is focused actually as "timber bamboo" and has recently been investigated in more detail by Londoño (2002): its extraordinarily rapid stem growth of up to 21 cm a day, diameter up to 22 cm, allows it to reach open spaces in the tree canopy at 20, or even up to 30 meters high within six months, but taking 4 or 5 years to reach maturity. Optimum growth is reached between 500 and 2500 m altitude, with rainfall of 1200 – 2500 mm per year, temperatures between 18 and 24 C, and 80 to 90 % humidity. It adapts well to Colombian tropical rainforest (with more than 10.000 mm precipitation per year), but not under too dry conditions (<800 mm per year). Culm densities in a clump are between 3.000 to 8.000 culms per ha (Londoño 1998, CVC 2000).

There are also reports about the extraordinary biomass fixation data for other bamboo species in subtropical China and tropical Indonesia. Bamboo ranking in general is outlined as number 5 of the world's fastest biomass producing genus (El Bassam, 2001). For our purpose we will focus on typical "American bamboos" like the *Chusquea* and the *Guadua* genus in Andean mountains. *Chusquea* is prevalent in altitudes of cloud forests from Colombia to Chile, quickly creating light green thickets, wherever a missing tree gives a chance in the canopy. In early colonial times, large settlements were found at these altitudes in Ecuador, Peru and Colombia, in these mountainous areas the Chusquea thickets are very common, but data is rare, so they will not be mentioned further in this essay.

Guadua is by far the most productive and widespread American bamboo genus, comprising 8 different giant species over the whole region and related Amazonian, Caribbean and Pacific river valleys, between Paraguay and Panama, even up to 2200 meters above sea level. *Guadua angustifolia's* highest genetic variety is located in the northern Andes (Marulanda et al. 2003), where its presence can be found almost at every creek and even in entire forests, but covering actually not more than 50.000 ha in Colombia, due to be considered widely as a weed.

Guadua as a Pioneer Plant

Guadua has an astonishing tolerance, growing in relatively acid (ph 4.2) to even poor soil conditions, able to cover a wide spreading range of precipitation, stands frequent inundation, as well as on well-drained soils like riverbanks; this plant grows almost everywhere and is a traditional competitor to agriculture and cattle pastures, as it rapidly takes over unattended fields and open land. Extinction efforts over decades promoted by cattle and crop farmers, are now strictly regulated by official environmental entities ("CARs") of the Colombian Government.

Fig.1: Young guadua culms from a neighborhood riverbank invading a sorghum field.

Although there have been reported dry biomass accumulation of 76,6 tons/ha (including associated flora like palms, trees and herbs), there are reported stands with 222 tons/ha (DeWilde, 1994), reaching more than 2/3 the biomass content of a natural mature hardwood forest in Colombia with about 322.2 tons/ha (Panama, Desmukh 1986). To link natural reforestation to this pioneer plant we count on recent investigations of biomass accumulation on newly established guadua plantations (400 culms/ha.), which have outlined over 21 tons of drymass or up to 10.8 tons C per year/ha (Riaño et al., 2002) and reaching 54.3 tons Carbon accumulation (8.600 culms, without associated flora) in a 6 year period of investigation, causing a CO_2 retention in the atmosphere of 195,84 tons (The specific weight relation of carbon and carbon dioxide is 1 to 3.6).

This productivity exceeds every endemic arboreal species by a factor of 3 to 4. Even subtropical trees like *Pinus oocarpa*, a dominant pioneer species in the Caribbean Islands and Coastal Central America, - areas which also were intensely populated by native tribes at the arrival of Columbus-, is reported with only 172 tons of biomass (1.200 plants/ha) on a rotation cycle of 18 years and remains under 10 tons biomass / year (5 tons Carbon). (IPEF Piracicaba, 1980).

In one kg of dry wood or bamboo, the following elements are basic (Wegener, 1999).

- 500 gr. Carbon
- 430 gr. Oxygen
- 60 gr. Hydrogen
- 1.5 gr. Minerals (Bamboo up to 2,6gr)
- 8.5 gr. Other Elements

To generate one ton of wood or bamboo, the following input is required, and the formula for oxigen production is essentially:

Input:		Output:	
Carbon dioxide	= 1851 kg.	Wood	= 1000 kg.
Water	= 1082 kg.	Water	= 541 kg.
		Oxygen	= 1392 kg.

Anatomical and Physiological Advantages

This phenomenon of extremely fast growing woody bamboo is combined with the following "pioneer" properties, giving advantage over other species in the same habitat:

- Mother plant offers starch through her root system to the young shoots and "boosts" the culm growth up to 21 cm per day, reaching the canopy in 6 months.
- Up to 30-meter long culms easily penetrate all bushes and weed crops, reaching the best light access, improving the mother plant as dominant species in recovered land. Even hot volcanic ash which burns all other vegetation will not harm the bamboo roots, so the culms thrive as one of the first of the returning plants (Hidalgo, 2002).
- C4 photosynthesis phenomena on the culm epidermis tissue, allows generation of power under low light conditions even without leaves (foliage is reported a C3) (Lopez *et al.* Unpublished, Riano N, 2003).
- New rhizomes thrive underground and spread the clump approximately on 1-2 meters per year in each direction - the fastest spreading sympodial bamboo.
- A "guttation" phenomenon, or water droplets from the leaves moisten the soil in the early morning, avoiding the dry out of the capillar effect of the soil, favoring rhizome penetration, water transport uphill and washing nutrients to the roots.
- Each culm part and especially the thorny branches on the lower part of the culm start to revive as soon as they contact humid soil. Vegetative propagation is the most common method in forestry. Wind broken young culms of 20 meters reach easily to the opposite riverbank and start rooting, so there is almost no geographical limitation in recovering unused terrain.
- Floating culms and branches, ripped away by floods and stranded on riverbanks, instantly create new clumps.
- Guadua shows no regular gregarious flowering like other sympodial bamboos in Asia, so it does not die out after flowering its flowering cycle of 35 to 40 years (Hidalgo, O: 2003). Vegetative propagation spreads more than 1 m/year.

Fig.2: Guadua culms and new shoots with associated flora

Natural Succession of Guadua - from invading fields to mature rainforest

Most descriptions of Guadua forests start with a paradigm: There is no typical pattern in the distribution of guadua with its associated flora, - depending on soil and climatological conditions, every investigated “guadual” (native word for Colombian bamboo stands) shows a different composition.

Humboldt already outlined “Guadua” as the dominant species in a variety of other tree species. Today there are documented 1005 associated species of flora, 29 mammals, and 54 birds, which led to official classification with a factor 0.5 of 1, as 1 being the national index on maximum biodiversity of the natural Colombian rain forests (Cipav, 2003). Some extremely commercially valuable tree species like Lauraceas, (which requires shade when young) and some valuable flowers, i.e. Heliconiaceae, are abundant in natural guadua stands.

The percentage of associated flora and fauna depends directly on the grade of development without interference. A natural guadual presents 3 stories of vegetation: herbs, up to 30 cm, bushes, 6 to 10 meters, trees > 40 meters.

The “guadual” starts to develop, as soon as it penetrates the competing pioneering weeds, like herbs and bushes with its fast growing culms. Once established, it dominates between 60 and 80 % of the biomass (deWilde R, 1993), downgrading slowly over centuries to give space as soon as tall trunks overcome the canopy. In Uraba, near the northern frontier to Panama, the *Guadua angustifolia* clumps cover only 40% of the forest, one story below the canopy of 40-meter high tropical trees. Further variety in biodiversity of “guaduales” depends also on the placement within the landscape. A survey on guadua locations in the Cauca valley registered 20% on top of hills, 47% on slopes, 33% on riverbanks and showed quite big differences in the distributions of the associated species (Ospina R, 2003).

A mature *Guadua angustifolia* "forest" only exists as highly managed clump. With selective culm harvest, extraordinary yearly biomass production and extraction is possible, but associated flora and fauna is artificially limited by the "cleaning" of weeds and shrubs. Sustainable systems with coexistence of productive and protective areas within the same clumps have been developed. (Camargo 2004, unpublished). Periodically harvested clumps become a more monocultural appearance (although still 20% asociated flora) and can pruduce up to 50 tons drymass per year and hectare.

Although in natural succession a tropical colombian rainforest reaches its maturity after 400 years, accumulating between 300 and 500 tons of biomass per ha (Saldariaga 1988), this bamboo could be the reforestation booster to generate the necessary initial biomass and mineral livestock for the later multistory rainforest.

To understand the symbiotic behavior in guadua plant physiology, we have to take into consideration the mineral properties of tropical soil: nutrients are permanently washed out and drain into the deeper soil. Guadua roots, usually associated with endo-microrhizzae, reach only 60 cm down into the soil, lest they could not access these minerals. Deeper-rooted arboreous species easily reach the minerals in the next horizons and transfer them into their lifecycle, so logically they are found in great variety in the Guadua clumps. Most of these species will never reach the sunlight; rotting and decomposition give life to microbiological fauna. Nutrients stay in the upper black soil, welcome by the guadua, - a perfect symbiosis (Liang, unpublished).

A complementary study on the "role of bamboo in secondary succession after slash and burn agriculture at lower elevations in North-east India" outlines the selective nutrient uptake of bamboo as a "conserver of nitrogen, phosphorus and potassium. Bamboo thus plays an important role in these ecological conditions.../... dominating the stress-tolerant shrubs and tree species for a long duration." (Rao, Ramakrishna, 1988).

This succesion pattern explains partly the enigmatic presence of over 185.000 km^2 of guadua-dominated forests in the Amazon, (reported by Griscom 1994, analyzed on 15 Landsat Satellite photos from 1976 www.yale.edu/ceo/DataArchive.html). Abundant "light green" patches on satellite photos in Peru/Brazil/Bolivia was found to be mostly *Guadua paniculata* and *Guadua weberbaueri* (Stern P, 2000), dominating plants which grip forest succesion for centuries at formerly intervened rainforest canopy and riverbanks. The causes of disturbance might have been floods, fire and anthropogenic reasons. Stern claims that actual presence of men cannot justify the abundance of these Guaduas as anthropogenic origin, but few investigators take into account the historic population density in the area, outlined by Erickson, 1998. Is the enormous population density of precolonial America the same missing link to explain the dominance of Guadua, the same enigma Humboldt was already concerned about?

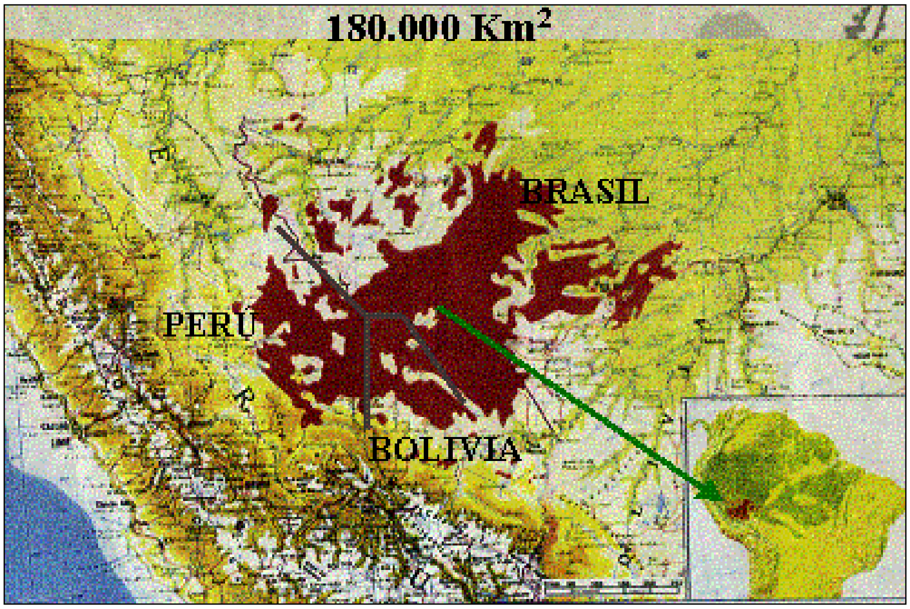

Fig.3:
Satellite photos of "Guadua" presence in Peru, Brazil and Bolivia. (Yale University)

- How did these widely spread bamboo forests develop, -was there a common origin?
- How much carbon sump effect is to be expected by a forest regrowth of 1000 ha?
- How much agricultural land did exist in the new continent before the arrival of Columbus?
- How can we link these data to the CO_2 curve, or "Hockey stick" phenomenon?

Guadua in human societies

Guadua has been used by American Indians since very early times for housing, defense for their villages, and hundreds of documented uses in hunting and agriculture. Guadua was cultivated long ago, and it is documented at least in Colombia and Ecuador, to be intimately associated with Amerindian homesteads for about 9000 years. The spanish historian Juan de Castellanos (1588) describes the native villages in the Cauca Valley as natural forts, circled with concentric lines of giant canes with spiny thorns...., to defeat human enemies and wild animals... (Moran, 2000). Another spanish historian of the first time of colonization, "Cieza de Leon" in 1553, already interprets the close bond between the native inhabitants and the widely distributed "guaduales" (in Quindio, eastern part of the Cauca Valley), as indication of large Indian population in past times (Patiño, 1957).

" Agriculture in tropical America began differentially some 10.000 years ago and was initially restricted to several but simple techniques such as garden plots and slash and burn. Paleological data on Andean Colombia, rich in its scope and temporal depth, indicates generalized forest clearing some 2000 years ago. Although productive cultigens were known in Colombia long before, it was not until about two millenia ago that an anthropogenic landscape dominated by agricultural fields was created. Although some records indicate abandonment of those fields before European arrival, the majority of pollen columns indicate a rapid forest recovery starting in the end of XV century, no doubt due to the collapse and/or relocation of the attendant population " (Faust / Gnecco C, 2003).

Fig.4: Native Bamboo house rebuilt in the Amazon of Ecuador, by Arq. Ladisich in 2002.

Hunter and gatherer, usually nomadic tribes, are rare in the Amazon and Choco rainforest, although they form our stereotypes of the original population. But the Amazon basin has plenty of native tribes, based on forest cultivation and sofisticated fishing. Heckenberger showed recently the archeological remains of widely spread complex settlements and largescale forest and wetland transformations of Xingu Landscape in the Amazon riversistem, during the last millenium with average population densites between 6 an 12 people/km^2.

Like in neolitic Europe, also in precolonial America, some complex societies with population densities of up to 80 persons per square kilometer farmland (average in Cauca Valley would be 25 to 35 P/km^2 , Friede, 1962) had developed, especially on potential fertile farmland like in some fertile areas as the Cauca Valley. The best described tribe are the "Quimbaya", famous for its goldart, on the eastern part of the Cauca Valley, which settled in an area of 1000 km^2, which even nowadays is one of the most densely populated areas in Colombia. The Spanish Conquistador Captain Robledo describes this society in 1539, " as the least warlike and least resistant tribe he had conquered..... It was also one of the most populated areas, dedicated to agriculture and giving two crops per year.... The land is hilly and the farmland surrounded by cane fields (Bamboos), a kind of crop rotation is practiced, the people are friendly and hand over easily their gold and their crops." (Friede 1962).

Demographical collapse in Quimbaya due to epidemic diseases

The first city in Quimbaya region, "Cartago" was founded in 1540, and the land was divided into tax entities called "encomiendas", registering every tributary native Indian "head of family". These counting's were repeated every 10 to 20 years, ordered by the Spanish emperor, who soon saw an erosion of his income and initially did not believe the decrease in population. This data is available for most of the colonial America and bears witness to the catastrophic descent of native American populations. The biological reason is clearly explained by the lack of immunity of New World populations to the quick sequence of introduction of Old World diseases, "unknown" bacteria and viruses, which have been assimilated by European and African populations during 10,000 years of settlement and cattle farming. (Jared Diamond, 1999)

In Cartago, Capital of Quimbaya region, there is a documentation in 1540 of over 15.000 (100%) taxpayers in about 300 “encomiendas”, starting with some 500 natives each. In 1628, there were only 69 left. There was almost no refugee to diseases like the “pest” reported in 1546. In 1559, there were reported 4.553 (30%), in 1568 only 2.876 (19.1%), in 1585 still 1.100 (7.4%), 1605 – two generations after the arrival of the spanish Captain Robledo – 140 (0.93%), and 1628, in the last counting, remain 69 (0.46%). The city of Cartago is abandoned “because there was nobody left to work the land” and re-found in 1693 in a different area, described as “cattle land”, so less personnel was needed for cattle than for farming. (Friede, 1962).

The following table is an evaluation of the 3 tallest and 3 smallest “encomiendas” in Cartago.

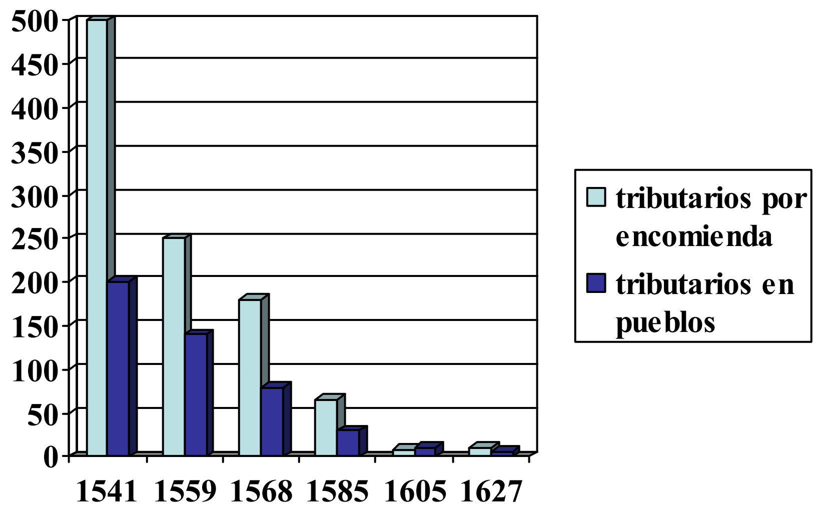

Fig.5:
Population collapse in Cartago “encomienda”, due to epidemic diseases (Friede, 1962)

The Quimbaya collapse is following a general pattern in America which started 1993 in the carribean Islands. With the second arrival of Columbus in “La Isabela”, there was an influenza epidemic on board, also called “pigs pest”, which brought the estimated 1.1 million of native population in Santo Domingo almost to extinction, in 1517 only 10.000 natives were alive (Guerra 1986, Estrella). A preconquest population of 25,2 millon is estimated for Central Mexico alone, sugguesting that there may have been over 100 million in the continent as a whole (Borah 1964). The demografic disaster had no known paralel in world history. In Peru the population fell from about 9 million to 600.000 in 1620 and Central Mexico collapsed from 25 million to about 1 million. By 1650 indians still existed in large numbers in the highlands, but in the tropical coastal lowlands and Caribbean islands they had disappeared and had been replaced as a source of labour supply by black slaves (Newson, L 1993).

In 1520, the “smallpox” crossed America from Mexico to Chile and killed probably a third to a half of the population before the arrival of Pizarro´s Troups. Although there might have been former waves of epidemics, the population initially recovered, because their social life was still able to overcome these impacts. But with the smallpox, -soon followed by measles, typhus, plague and influenza,- begins the demographical catastrophe, which took its bottom line around 1620.

By 1650 maybe a million *whites* were present in Spanish America, many of whom were actually *mestizos*, and there were another 70.000 in Brasil. Meanwhile about half a million *blacks* had crossed the Atlantic (Mc Alister 1984:344).

When the missions started to enter the amazon basin in second half of 17 century, most of the cultures and big cities still mentioned in 1546 by Francisco de Orrellana, had already vanished after their first contact with Old world diseases about 100 years ago. The missions recollected the lost survivors, protected them from slavery and provided unvoluntarily the next dosis of lethal germs. The description of these groups as hunter and gatherers does not reveal a glance of the culture they lost in 100 years of agonizing decense, since Orellana shipped down the Amazon river and left lthal germs. Linda Newson is probably neglecting this fact when describing “the tropical lowlands like the Amazon basin as inhabited by hunter and gatherers and forming an almost uninhabited buffer zone which is likely to have impeded the spread of disease”.

Population recovery rate is so low for the next 200 years that there were hardly enough men in the american colonies to fight the revoluionary indipendence wars against Spain in 1820, meanwhile the forest recovered the abandoned farms and fields.

300 years of natural forest recovery

When forests started to reclaim the gradually abandoned land, how much time was required to cover one square kilometer of farmland?

The following graphic shows the time necessary to invade with only 1 meter (of vegetative) expansion per year, in a simplified Quimbayan landscape, for guadua stands around the villages and on the riverbanks: after 250 to 300 years there would be no farmland left, even without considering additional vegetation brought in by seeds of other pioneer plants.

Although nature does not respect mathematics, there is an estimation that could approach theoretically the progressive biomass accumulation during expansion. Consider a linear or radial progression below in the model of forest invasion. This formula finds its practical limit when approaching to the climax of the mature tropical rainforest, but real data has not been found in literature. Guadua fixes 9 tons of Carbon per ha/year, which equals 18 tons of dry Biomass, (Riaño et all, 2003), but only half of that value is put into the following account, taking in mind that guadua is dominant, but not the only species in the landscape.
With 1 meter per year incursion of guadua into farm land and conservative 10 tons of biomass/ha/year a 100 lineal meter front will cover 10 ha in 10 years and accumulate 550

tons, in 20 years 20 ha, but with 4 times as much biomass: 2200 tons, (or 110 tons per hectare). One square kilometer is probably covered in less than 250 years and will reach easily reach climax rainforest biomass accumulation of 30.000 to 40.000 tons.

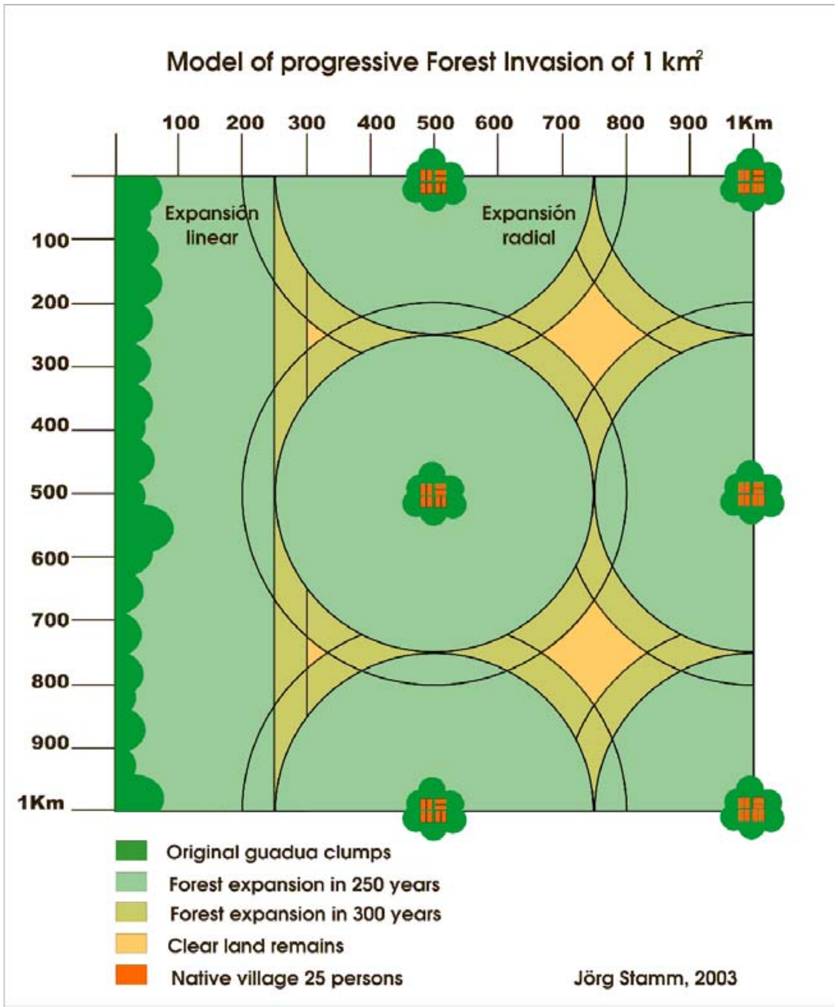

Fig.6: Forest expansion on 100 hectare, river and guadua surrounded villages each 500m.

Based on Friede and his documentation of population density of 60 to 80 capita per km2 in the populated area of Quimbaya tribe, there is matematical distribution model of 4 villages with 15 to 20 persons each, every 500 meters in distance. According to "Juan de Castellanos" and other historians the villages were frequently hidden by guadua clumps, still today almost each farm and even individual houses counts on a little "guadual", still essential part of their daily needs in agriculture and construction.

Within two centuries later, when Humboldt walked through the area describing and classifying the vegetation of the Cauca Valley, almost all the abandoned land was already covered with forests, mostly guadua. Major tree species had not yet penetrated the canopy. He did not know of the demographic catastrophe, so he had no explanation for this phenomenon of unfinished succession. The historic cultures have been forgotten and there were almost no remains when the recolonization of the Cauca Valley started in 1850, led by treasure hunters and cattle farmers, describing the imense guaduales and their struggle to "clean" the landscape. Today the forest remains are limited to riverbanks and steep slopes.

Major guadua spots in the Amazon region can be explained by the same pattern. Guadua could be used be used as an indicator species for archeological sites, precolonial ceramic evidence might be easy to find in the new settlements of Bolivia and Southern Brasil, where actually big patches of bamboo are slashed and burned down for extensive cattlefarming. Might it be a reinvasion of human ocuppancy in these areas? Presence of Guadua on satellite photos allows estimates on posible former distribution of major human settlements in the Amazon. Population density today is still lower than 2 people per km^2, but historical data about cities (Francisco de Orellana, 1946) indicates a far higher population density. For areas of white water rivers in the Amazon population averages are estimated 14 people/km^2 (Fittkau, 1987). Recent investigations on “terra preta” locations in Brasil and Bolivia confirm these population densities (Heckenberger, 2003, Erickson, 2001).

Farmland to Forest conversion

The estimated total amount of farmland and population density in pre-colonial America has been discussed for decades and investigation estimates up to 112 million people (Dobyns 1966). Depending on fertility of land and landscape, the extinction rate (dead / survivour during plagues) has been in a ratio of 60 to 1 in fertile fluvial and highly populated areas, like the Guayas river basin in Ecuador, where thousands of ha of “raised fields” are still to be seen. Colder habitats like the high Andean valleys have been less populated and less affected by epidemic diseases and are estimated only with 5 to 1 extinction rate (Newson L, 1993). A general quoting might have been 25 to 1, and a generally accepted estimation is a minimum 95% extinction of Americas native population.

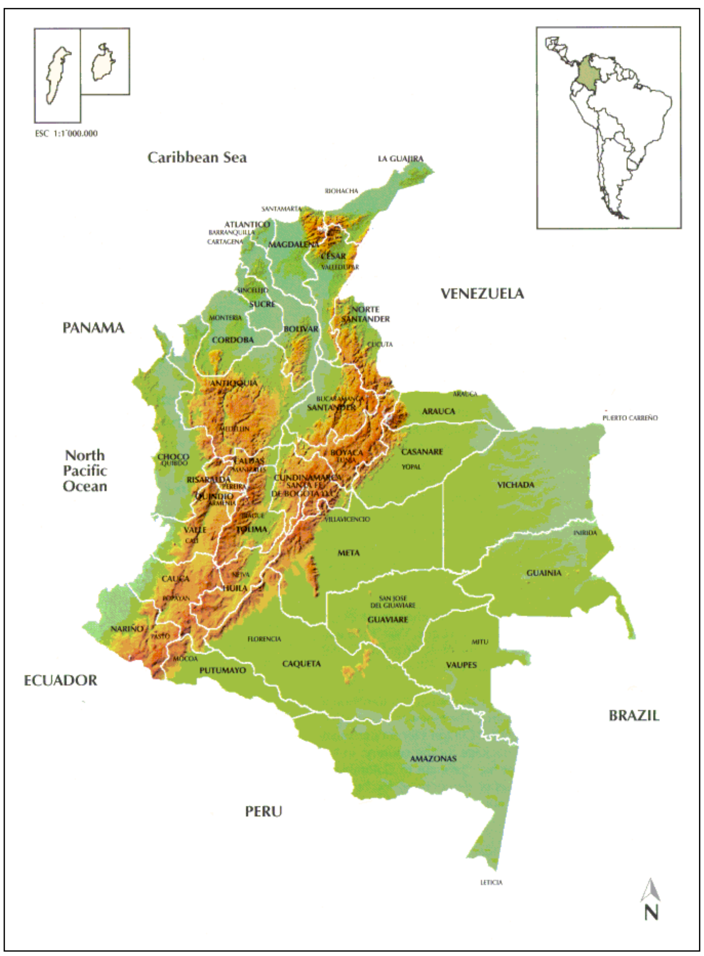

Fig.7: Territory of Colombia, with about 1´140.000 km^2 and an actual population density of 40 people / km^2, but 75% urban settlement. Colombia recovered its estimated precolonial population of 15 to 20 millon people only half a century ago.

Estimating 1 ha as a average farmland requiered to sustain one person, about 100 million ha, or 1 million square kilometers in the Americas were ready to be covered by forests within the next 250 to 300 years. Increased population density in the early 19 century required again more farmland, but actual rural population densities in Colombia with less than 20 p/km2 do not reach precolumbian standards until today.

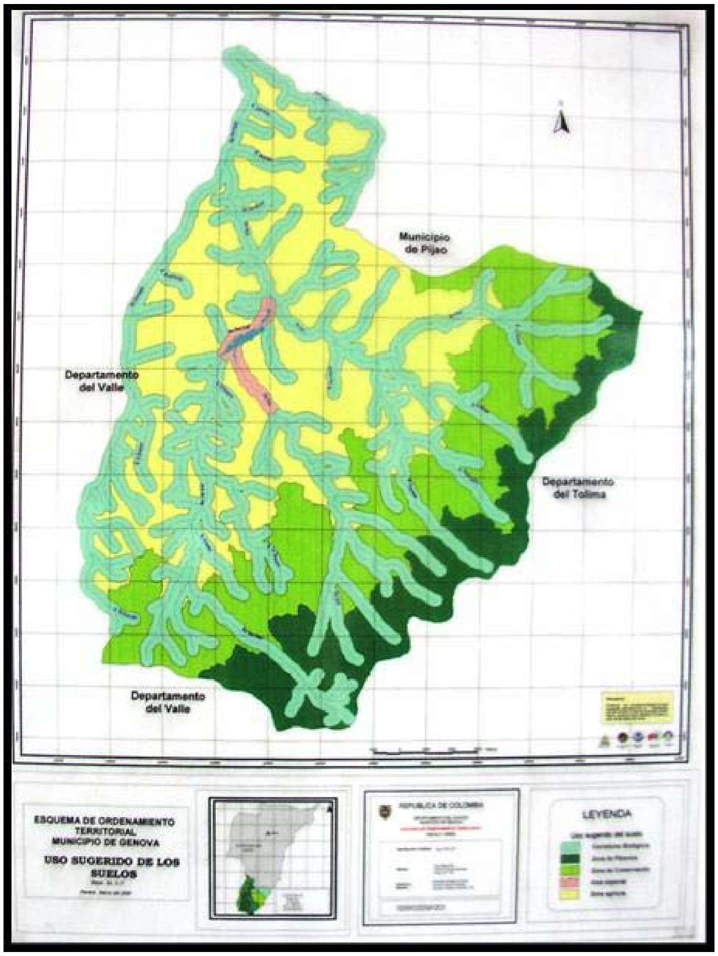

Fig. 8: Forest remains along rivers in Quimbaya area (Quindio)

This map of Genova (Quindio, Cauca Valley) is part of the regional devellopment plan and outlines the riversystem as a biological corredor. A 200 meter wide protected area for reforestation and wildlife reserve, penetrates almost every part of the three climatic stories between 1200 (yellow) and 4000 m (dark green) over Sea level. The vegetation in these riversystems was also responable for the quick recovery of forests.

Carbon sump and the Little Ice Age

The "Little Ice Age" is a well documented climate phenomenon between 1300 and 1850, when extremely severe winters in Europe caused unsual weather threatenings, like glacier advance in the Alps, a completely frozen river Thames, severe famines and migration. There are a lot of explanations for the temprerature drops, like darkended sky from volcano eruptions and supposed changes in sunspot activities, but anthropogenic influences have been generally neglected so far. The commonly acepted human impact on climate starting at least during the "Industrial Revolution", by the massive fossil fuel uses in steel fabrication and in steam machines invented by James Wattt in 1765.

Michael Williams shows already a progressive golabal deforestation from 8000 B.C. and concludes that preindustrial worldwide forest reduction of 7 to 8 million km^2 is responsable for the slow rising CO_2 level. "...Fire and browsing animals can wreak havoc in forest areas wiht little effort. Neolitic agriculture and settlement had far more spatial and chronological diversity than once thought. Settlement and agriculture were stable in many locations." He mentiones the anthropogenic charcoal locations in the Amazon and Mayan area "as evidence for successive resource management" by precolumbian natives. "In the Americas, the introduction of pathogens after 1492 led to a demografic collapse from at least 53,9 million in 1492 to only 5-6 million in 1650, an 89% fall. Land abandonment was widespread and the forest increased in extent and density, so that in 1750 America was probably more forested than it had been in 1492. (Williams, 2000)

The “Hockey Stick” phenomenon of CO_2 data is already acknowledged at World Climate discussions, but recent investigations at Law Dome, Antartica, on a more detailed resolution were made by Etheridge et al. 1996, and described an irregular hamock in the curve of CO_2 mixing ratio in his Antarctic Ice core Data, which he concludes as: “it must have been a change in land use”.

This curve shows in 1540 an unexpected decent, starting with 283.1 ppm and sinking rapidly until 1615 with 275.3 ppm - an astonishing parallel to the population decrease in America and obvious forest recovery. It takes almost another 200 years until in 1805, when it reaches again the lowest mark of 283.4 ppm and grows continuously until the threatening 329.4 ppm in 1975 (Etheridge 1996).

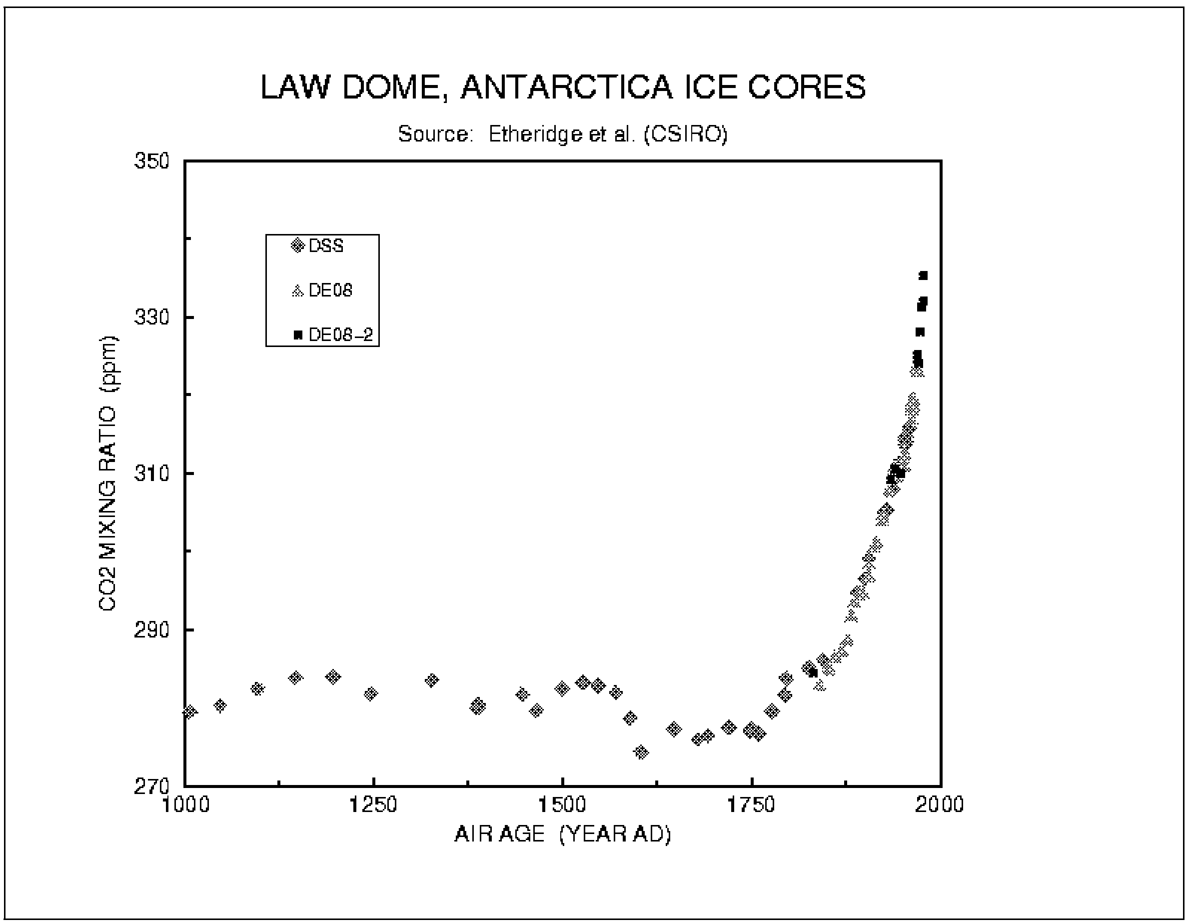

Fig.9: Carbon dioxide mixing ratio in Antarctic ice cores, Etheridge et al. 1996.

Ruddiman in 2003, points out that "a wide array of evidence on forest clearance since 8000 and rice cultivation since 5000 years caused and average warming of 0,8 C and even 2 C at high latitudes."

"CO_2 oscillations of ~ 10 ppm in the last 1000 years can be explained by outbreaks of bubonic plague that caused farm abandonment in western Eurasia. Forest regrowth on abandoned farms sequestered enough carbon to account for the observed CO_2 decreases. Plague driven CO_2 changes were also significant cuasal factor in temerature changes during the Little Ice Age from 1300 to 1900 AD. " (Ruddiman, 2003).

Taking in mind the Carbon uptake by deep ocean in larger scale CO_2 annomalies he concludes that a ~35 to ~ 90 GtC would be needed to explain the CO_2 decreases of 4 to 10 ppm. The Black Death Pandemic of 1347-1352 AD appears correlative with a CO_2 anomaly of -5 to -10 ppm in the ice core records. The second drop between 1550 and 1800 is also interpreted as consequence to depopulation in Europe and America due to plagues, but his calculations still subestimate the amount of the formerly cultivated land and the plagues impact of the new world.

Fig. 10: Raised fields from precolombian times at Guayas river basin in Ecuador are found in large extension and give testimony about sofisticated water and land management of the former native population.

If in only in Quimbaya Area of 1000km^2, some 60 – 80.000 ha of farmland is estimated to feed 60 to 80 thousand natives, then 60 to 80 % of populated area described by Friede in are gradually recovered by guadua and associated forests. After 100 years of undisturbed growth (one meter a year = 10 tons of biomass accumulation per each 100 meters of width), the first square kilometer of mature forest on the best soils with 550 tons/ha of dry biomass or 27.000 tons carbon sump per km^2 is calculated for Quimbaya region. Studies of biomass accumulation in a ususal secondary forest, 35 years after slash and burn practice, have shown to be 130 tons, or 3.5 tons per ha/year, (Saldariaga et al 1988). The tropical humid and rainforests in general contain 155 and 187 tons of carbon per hectare in the aerial biomass (Brown 1990), and forests in general fix between 20 and 100 times more carbon per hectare than agricultural fields (Houghton 1990, Data from Guariguata 2002). This comparison with the data of

normal secondary forests in natural succesion has to be taken just as a trend indicator, but *guadua angustifolia* as secondary forest indicates to be much faster, reason enough to integrate this pioneering timber bamboo into forestry programs.
Soils don't allow everywhere in America these 550 tons of forest biomass retention as estimated for the fertile Quimbaya region. Fires and other natural factors could interfere and release CO_2. But 10.000 tons of carbon sump per km^2 (or 100 tons per ha) is a conservative estimate for a continental perspective on secundary forest. About 1 million km^2 (or 100 million hectare) of recovered forests could be responsible for about 10 billion tons of carbon sump (or 36 billion tons of CO_2) in the world's atmosphere. Due to climatologist Hermann Mannstein even half of that amount would explain the unexpected hanger in the CO_2 mixing ratio between 1540 and 1805 and an average cooling of the world climate of aprox. 0,2 degrees Celsius. "In addition to the impact on the CO_2 level and the resulting radiative forcing also changes in regional climate are probable: enhanced evaportranspiration and water storage in the reforested areas. Together with the reduced radiative forcing due to lowered atmosferic CO_2 levels (inverted greenhouse effect), the demografic collapse of the native population of the Americas can be offered as an aditional factor that forced the North Atlantic into the climate pattern known as Little Ice Age"(Faust et al. 2004).

Discussion

The same reforested area would not have the same effect today, due to the fact that the gap of 7,8 ppm CO_2 between a 275,3 and a 283,1 ppm mixing ratio in the 16 century is about 3,1 %, but at a mixing ratio of 375 ppm it covers only 2,3 % at the end of 20 century. But it is still an ecouraging argument for world wide promotion of massive reforestation.

This coincidence of population decrease, reforestation, carbon sump and climate change is for the first time linked by data. The catastrophic collapse of a quarter of the world's population is offered as the historic missing link; Columbus did cause the "Little Ice Age."

Recent the epidemic outbreak of "SARS" showed that viruses are threatening worlds population even today. Although quickly rising sealevels are threatening todays lowland coasts, but nobody really wants to repeat the historic chain of epidemic outbreak of diseases and its successions. This historic showcase outlines the eficciency on climate change by reforestation in big scale, easy to repeat on worlds vast overexploited or unattended areas.

There are vast areas in Colombia, degraded by extensive, inefficent cattle farming and following erosion, but also by the "burned land" practice of governmental anti-drug campains (350.000 ha). Most of this land is actually unused due to lack of security and lack of investment. Due to the national devellopment plan only 180.000 hectare are to be reforested in the next three years, but another 1,5 million ha of the national territory are outlined as destinated to reforestation, although they cannot be financed by national budget.

Industrial Processing of timber bamboo in selective harvesting offers already after the first decade of reforestation an aceptable return on investment, so that the valuable tree species can grow untouched in between the guadua forests until being out of harm.

Conclusion:

- Population decrease and natural recovery of forests is linked by a causal chain to the climatological phenomenon of the "Little Ice Age".
- The fast declining demographical curve between 1540 and 1615 is directly correlated with the fast declining curve in the CO_2 mixing ratio of Antarctica ice cores, a consequence of the quickly expanding forest in about one million square kilometers of the New World.
- This fast recovery is only possible by the extraordinary fast biomass growth of pioneers like pine trees in the subtropical and *Guadua* in the tropical latitudes.
- This argumentation is much more "terrestrial" than former theories and should be approached from each related scientific branch, as it is a combination of usually unrelated branches of science like forestry, anthropology and meteorology.
- Especially the fast growing bamboos are a key factor in the quick forest recovery and further succession to mature rainforest. Because of this key role between forestry and climate change, these "gramineas" with its extraordinary carbon sump effect, should be immediately added to the Kyoto Protocol.
- Guadua is an excelent pioneer for establishment of biological corredors, for example on cattle land between isolated wildlife habitats.
- Massive reforestation in the tropics with the "timber bamboo" *guadua angustifolia*, combined with industrial processing of the selective harvested culms, offers sustainable, near-term income for investors and farmers.

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Weights and Mesures:

1 ha = one hectare (10.000 square meters, or 2,47 acres)
1 km^2 = one square kilometre (100 hectares, or 0,386 square miles)
1 ton = one metric ton (1000 kg, or 1,102 U.S. tons)
1 GtC = one Giga ton Carbon = one million tons of Carbon = 10^9 tons.