The Oil Drum: Europe
DISCUSSIONS ABOUT ENERGY AND OUR FUTURE

From sweet on the table to fuel in the tank: the millenary history of Sugar Cane

Posted by Luis de Sousa on March 23, 2007 - 11:05am in The Oil Drum: Europe
Topic: Alternative energy
Tags: alternatives, biofuel, brazil, environment, ethanol, history, slavery, sugar cane [list all tags]

Sugar Cane is back in the news. With oil prices resembling those of the early 1980s, it seems that all those efforts made by then in Brasil to step-up ethanol production make sense again. With the promise of a high energy return and a renewable production cycle, the cane culture might be set for a return.

It won't take long to start hearing about sugar cane successfully planted and converted to ethanol closer to home than expected. But before the cane hype gets installed, please take a dive into the fascinating history of a plant that shaped the World.

This article has a Companion that adds geographic information to the text. A Google Earth file can be found here for download; when a mark like [Pxx] appears in the text double click in the corresponding placemark to get a view of the geographic location in focus.

What is it?

It is a plant from the gramineae family remarkable in harvesting the energy from the sun. It grows with a stout and fibrous stalk formed by several joints that's highly rich in sucrose. It produces small flowers forming pending spikes at the top. Depending on the breed it can grow from 3 to 6 meters high, with a stalk 2 to 5 centimeters thick.

A Cuban cane cutter sharpenning his blade. Click for more.

Although mechanized harvest has been evolving, sugar cane is still mostly cut by hand throughout the world. The tool used by cutters is a steel blade 50 centimeters long widening to 15 centimeters at its tip. Yielding is made by cutting down the cane, clearing the leaves (sometimes with the help of a hook at the blade's end) and giving

a final cut on its top at the level of the last mature joint. The stalks are then pilled and collected in beams by hand or mechanically. The beams are then carried to a mill where they are triturated into a broth that is the base of the final products.

Brasil is by far the largest sugar cane producer in the world, although the culture is almost universal in Tropical regions, were it benefits from the alternating humid and dry seasons. Although sugar is its most popular product, the cane juice is also used to produce syrup, molasses, rum, firewater (called *cachaça in Brasil) and alcohol used as fuel. Among the residues of the sugar cane crushing is the bagasse than can be used as a heat source, powering the mills or producing electricity. A mix of cane yeast and bagasse is also used as feed stock, and another residue, in Brasil called cane wine, can be used as fertilizer.*

In the southeast of Brasil sugar cane is planted from October to March and harvested from May to October; in the north it is planted from July to November and harvested from December to May. Circa 80% of Brasil's harvest is done by hand, employing more than 1 million workers. Varying with local environment conditions the annual harvest can go from 50 to 100 tones per hectare, the mean for Brasil is 60 tones per hectare. From this mass the sugar content extracted can go from 9% to 12%, whereas the volume of ethanol obtained stays around 70 liters per tone.

Origins and first migrations

Although still a matter open to discussion, sugar cane is commonly referenced as originary from Papua New Guinea, appearing between 10000 and 12000 years ago. Other possible origin is Western Polynesia, but due to the proximity of these territories and a high number of hybrid species, it is impossible to know exactly where sugar cane first germinated [P01].


Darius I of Persia. Click for more.

By 3000 B.C. the plant had slowly traveled north through tropical Asia to the Malaysian Peninsula, Indochina and the Bay of Bengal. At this time the plant's products weren't yet subject to trade, its production was mainly as a subsistence culture [P02].

Sugar cane was first introduced into China circa 800 B.C., at the time still used as syrup [P03]. It is only by 400 B.C. that the first raw sugar is made by crystallizing the syrup. At this point the culture is widespread throughout East Asia, clearly testing the tropical limits.

By 500 B.C. emperor Darius I of Persia sends several expeditions to the East (among them one exploring the Indus River) cementing the economic fabric of his empire. It is believed that in consequence of these expeditions sugar cane is eventually brought back to Persia. There it would be cherished as a high luxury item and kept secret from the rest of the western world. By this time the culture as clearly left the Tropics behind [P04].

The Arab Conquest

> The word from which the name sugar originated is, probably, "grain", "sarkar", in Sanskrit.

In the eastern part of India, sugar was called "shekar", while the Arab people knew it as "al zucar", which was transformed into the Spanish "azucar", and from there, to "açúcar", in Portuguese.

In France, sugar is called "sucre" and, in Germany, "zucker", and from there into English "sugar".

By 610 Prophet Muhammad received his first revelation from God, originating a new monotheistic religion. Under this new faith Prophet Muhammad united most of the Arabic Peninsula, especially after the conquest of his home city, Mecca. From there the Arabs would swiftly gain control of the Middle East and its surroundings, consolidating and spreading the Muslim faith.

Prophet Muhammad preaching in Mecca. Click for more.

During the first half of the VII century, the Umayyad Caliphate (an almost informal political setting that aroused from Prophet Muhammad's conquests) spread to Syria in the north, Egypt in the east and Persia in the west. In Persia the Arabs found the sugar cane, and understanding its potential, not only brought its culture to the west but also created the first large scale sugar trade [P05].

In 640 the culture had already reached the Mediterranean environment; it would then enter North Africa were the superior Egyptian chemistry would propel its fast spreading [P06]. The trade brings sugar to Europe for the Caliphate profit; sugar cane becomes itself a fuel of the Caliphate expansion.

In 711 the Arab lords conquered Gibraltar, finally entering Europe, bringing with them, among other novelties and innovations, the sugar cane culture. The first plantations in the continent were in what is now the Algarve and Andalucía circa 750, from there expanding to other parts of Europe [P07].

Rise of the Umayyad Caliphate. Click for more.

Rise of the Umayyad Caliphate. Click for more.

In Europe the plant showed again its appetence for the humid islander environment. Especially in Sicily, were it arrived in 950, and in Crete, sugar cane was a successful culture [P08]. By the XIV century the plant had spread entirely through out the European Mediterranean, now testing the forties. But production was insufficient and sugar was still imported from the East, especially India. Venice hold the refining monopoly, and the trade routs from India were mostly controlled by the successors of the Caliphate.

At the same time the Crusades are coming to an unsuccessful end, with the Ottoman Empire rising and moving west. Sugar can cost the equivalent of today's 100$ per kilogram in Europe; the scene is set for the next step in expansion.

Atlantic Expansion

At beginning of the XV century Christian Europe is importing commodities (sugar, pepper, cinnamon, etc) from the Far East trough land routes controlled by the Muslim lords; prices are very high, performing a

significant wealth transfer from Europe to the Middle East and North Africa. At the westernmost tip of the continent, Portugal is one of the most helpless states, and is the first to try to change the situation.

The Caravel, the ship that made the Atlantic discovery in the XV century. Click for more.

The strategy is set towards the sea, with the prospect of finding a maritime route to India, overriding the land routes controlled by the Arab lords. At this time the Atlantic was almost completely unknown to the Europeans, apart from the African coast down to the Bojador cape, for high sea faring was outside their knowledge. In this setting Prince Henry assembles a research center in Algarve, drawing together mathematicians, cartographers, engineers, etc, that would create the technology needed to face the open Atlantic.

The Atlantic exploration happens relatively fast; based on maritime trade, the further it goes the larger the profits it generates, sponsoring further exploration. The maritime route to India was finally established in 1498; at the time there wasn't much left to explore in the Atlantic.

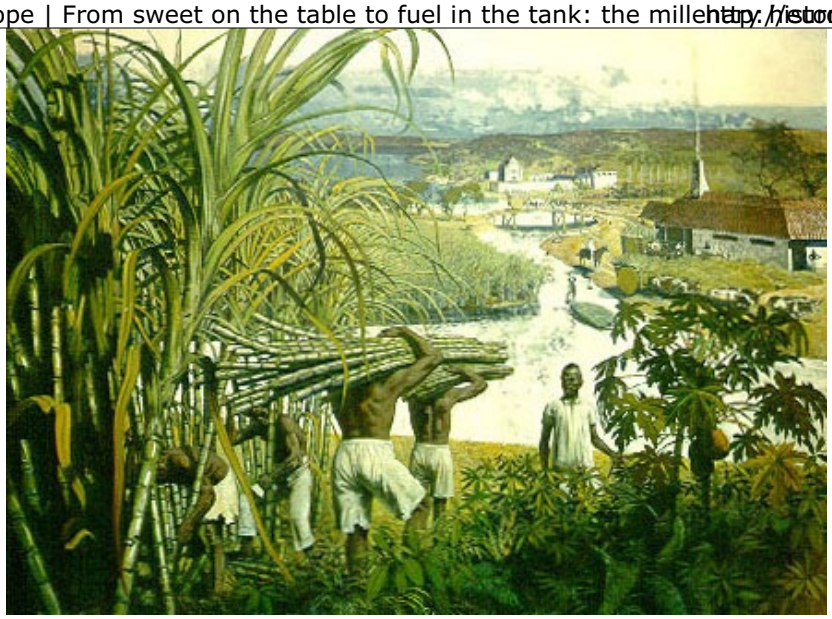
As a way to make the newfound inhabited land profitable, Prince Henry sent for sugar cane specialists from Sicily to start its culture in Madeira in 1425 [P09]. At this time the maritime expansion was mainly sponsored by precious metals brought from Africa's coasts, but during the later part of the XV century sugar cane started to have a leading role. Under King John II's reign the plant would be brought to all inhabited archipelagos found by the Portuguese: Canary Islands in 1480 (later offered to the Spanish Crown), Cape Verde in 1490 and from there to São Tomé [P10]. In 1493 Columbus brought the first sugar seedlings to the Caribbean, planted in the island of Hispaniola [P11], but trade from the West Indies would only begin some decades later. In less than a century sugar cane was back to the Equator.

The Sugar Boom

Trade from the New World would start only in the XIV century with the building of the first sugar mill in Hispaniola in 1516. The culture would then start to spread throughout the Caribbean, by the 1530s it had been introduced to Cuba, Mexico, Colombia, Venezuela, Puerto Rico and Peru.

But the big industry explosion would happen in Brasil. Following a Crown decree promoting the expansion of sugar trade, an expedition led by Martim Afonso de Sousa builds the first sugar mill in Brasil, near what is now São Paulo [P12]. The culture would head north from there, towards warmer climate arriving at Pernambuco - sugar land.

Circa 1550 a German traveler by the name of Hans Staden embarked on an expedition to the River Plate. After some nautical incidents the explorers found themselves stuck at São Marco, from where Staden is captured by a party of Tupinamba Indians. In spite of several efforts from the Portuguese to negotiate his release, Staden is kept captive for more than two years before managing to escape. He returns to Germany on a French ship and writes a book on his experience ("Among the Wild Tribes of Eastern Brasil"). This book is a remarkable document of life in the New World at the epoch; in it Staden reports that by 1540, from Pernambuco to Surinam there were already 2000 sugar mills operating, and 800 more in the island of Santa Catarina. [P13].



Harvesting sugar cane in Brasil by Julius Moessel. Click for more.

Such number of mills included thousands of iron cast machinery components: gears, levers, axles, etc. Demand for such parts fueled an explosion in mold making and iron casting in Europe, with many craftsmen and blacksmiths specializing in this type of machinery. The sugar cane trade was the great rehearsal for the Industrial Revolution.

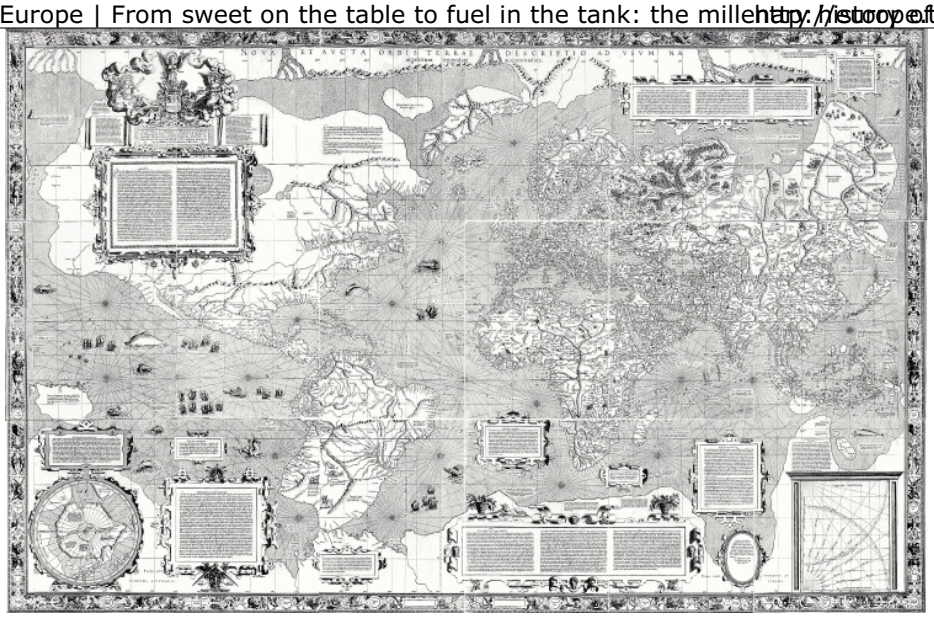
The Dutch expansion

In 1580 Portugal broke under the weight of Inquisition, which disbanded the human capital that made the expansion possible. With a teenage king missing in action in Africa, the closer successor left was King Philip of Spain. Both countries merged under King Philip's rule creating an immense empire. At the time Spain was at war with the Dutch; it was in Holland and Flanders that most refineries existed and it was here that most of the sugar from Brasil was refined.

The Dutch assuming control of most of the production in the Northeast coast of Brasil, up to the mid of the XVII century when Portugal and Spain parted ways. They also expanded the sugar cane culture in the Caribbean, starting in Barbados and going all the way north trough the smaller isles up to the Virgin Islands[P14]. The Dutch expansion was possible for in their turn they proceeded with the technological progress. They developed new larger ships more suitable for the trade and adopted the Mercator cartographic projection, which produced charts where for the first time a maritime route with constant compass would be a straight line.

A Dutch ship from circa 1600. Click for more.

In parallel with the Dutch the Spanish also stepped up production in the Caribbean, especially in its bigger island, Cuba. In order to reduce their dependence on imported sugar, the French and the British would also set in for their share, first through piracy then by also settling. The British would strive in Jamaica, the French in Saint-Domingue. These were the wild days in the Caribbean.



The Mercator projection. Click for more.

The Sugar Triangle

> [...] people all coloured of the same night, working vividly, and moaning all at the same time without moment of truce, nor rest; he who sees the machine and the confuse and strident apparatus of that Babylon, can not doubt, even having seen Etnas and Vesuviuses, that such is a resemblance of Hell.
>
> Father António Vieira, 1633.

African slaves harvesting sugar cane. Click for more.

Sugar cane cutting was (and still is) a highly demanding hand labour task. The European settlers couldn't possibly provide the numbers needed for that, they had to recur to slavery. At first they tried to enslave the indigenous folk, which were still close to the Stone Age, but such would rapidly fall short of their needs. In the beginning the Indians vastly outnumbered the settlers, which would be happy with a peaceful co-existence, avoiding conflicts. Later, the alien diseases brought from Europe by the settlers would decimate the indigenous populations.

The Europeans resorted to slaves brought from Africa. Strong built folk, resistant both to the diseases brought from Europe and local ones like malaria; they were sacrificed to make the sugar boom possible in the West Indies.

The final pillar of the Sugar Industry was completed, creating what would become known as the Sugar Triangle. This name refers to the route that traders would make to bring sugar to Europe. Ships would sail out from the old continent bound to the African shores. There they would buy all the slaves they could fit in the under deck without choking. Slaves stacked they would sail towards Brasil or the Caribbean in a swift voyage. At sugar land they'd unload the slaves that had survived the trip, and would load up with raw sugar. The next step would be the return to Europe; once there the sugar would be unloaded for the final refinement and the ship would be refitted for another triangular commission [P15].

The Sugar Triangle was the stage of the largest migration phenomenon at the global scale. Millions of Africans were thus forced to abandon their homeland just to die in a gruesome voyage to the New World or live for the rest of their lives as cane cutters. In the XIX century, after the decline of the sugar cane industry (see below) the Sugar Triangle would be replaced by the Cotton Triangle that would prolong the migration up the slavery abolishment.

Slaves below deck. Click for more.

Facing the limits

> Someone has already quite rightly said that the sugar cane culture is processed in an autophagic regime: the cane devours everything around it, engulfing more and more land, dissolving the topsoil, annihilating the smaller helpless cultures and the human capital itself, from which the culture drains all life. Such is the pure truth...
>
> Josué de Castro, *Geografia da Fome*, Rio de Janeiro, 1952.

There was a problem with sugar cane, it was a very demanding culture, and to make it worse the milling process was very energy intensive. The regime is simple: to start with the forest is chopped down or burnt to make way for the cane, and then the wood is burned in the mills to crystallize the cane juice into sugar. By the XVIII century in Brasil every kilogram of sugar required 15 kilograms of wood.

Deforestation. Click for more.

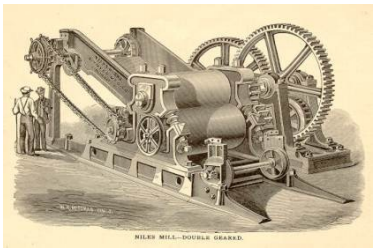
The cane prefers the warmer and humid climates; this is why most of the text so far has been focusing on islands. It is in the islands that the destructive power of the cane is felt more rapidly. Madeira (the Portuguese word for wood) was deforested in a century, also in the Canary Islands resource limits were faced still in the XVI century. Apart from Cuba all the Caribbean islands would face severe resource constraints in the XVII century; by 1700 sugar had become once more a highly expensive commodity.

In the main land the extensive Atlantic forest would disguise these limits. This is why the cane would endure in Brasil were both the climate and the wood supply were favourable. Still, in 1990 the Brasilian Atlantic forest was 8% of what the Portuguese explorers found at the end of the XV century.

The Brasilian Atlantic forest; in yellow the original area, in green the ramaining. Click for more.

Back to the Caribbean

This constrained environment provided for some important developments. The milling is a process where the cane juice is boiled into progressively heavier molecules, typically in three or four furnaces. In 1650 it was invented in Jamaica the Jamaican Train, a process that would allow the several furnaces to be heated with a single fire [P16]. The wood requirements drop sharply, and this new process starts to spread through out the Caribbean.



Steam powered Sugar Mill. Click for more.

By the middle of the XVIII century with high competition between the colonial powers and the spread of the refineries in Europe, the price of sugar drops until it becomes a basic food commodity. With the industry in decline in Brasil (where gold had become a major source of wealth) the Caribbean emerges as the largest producer in the world; Guadaloupe, Barbados, Saint-Domingue, Jamaica, had turn their economies almost entirely to the cane culture. In this century Britain succeeds the Dutch as the major maritime power, and is successful in eradicating piracy from the Caribbean.

In 1751 sugar cane is introduced in Louisiana. The final stage of developments on the milling process unfolds relieving further the burden on the forest. The cane bagasse is used as a fuel, partially substituting lumber, animal manure is used to fertilize the soil, and in the second half of the XVIII century the steam powered mills starts to propagate. It is in Louisiana that an important invention takes place, the vacuum boiler, created by Norbert Rillieux in the 1820s [P17]. The milling process becomes much more efficient, evolving towards full steam-powered mechanization, reducing the hand labour intensity.

Norbert Rillieux's vacuum system. Click for more.

Decline

By the turn of the XIX century the Napoleonic wars had already grown into a major conflict, stalemate unfolded with Britain maintaining naval supremacy and Napoleon controlling most of continental Europe. The raw sugar can not reach the refineries in the continent, and in 1813 Napoleon simply bans sugar imports [P18].

Beet, a modern source of sugar. Click for more.

It is this setting that the work of German researchers Andreas Marggraf and Franz Archard, who found sucrose in beet roots and built a sugar beet mill in previous decades, is put to service. Fueled by the industrial revolution the sugar beet industry develops rapidly creating a serious competitor to the cane industry; raw sugar doesn't have to travel from the New World to the refineries and the hand labour cost is lower.

The abolishment of slavery that put an end to the endless flow of man power, and the discovery of saccharin, an artificial sweetener, were in their turn two important elements in the decline of cane culture. At the start of the XX century most territories in the Caribbean had become independent from the colonial powers, a fact not disconnected with the decline of the sugar trade.

Resurrection

Throughout the XX century many of the countries where sugar was traded in the colonial times kept producing, taking advantage of low wages, but sugar was by no means the main economic activity it was in the past. Since being in a favourable environment the cane also kept growing wildly in the Caribbean and Basil.

In the 1970s the cane culture would come back to life as an answer to the oil crisis lived at the time. In 1975 the brasilian government, with help of the World Bank, set on a programme to reduce the country's reliance on foreign oil. Called Pro-Álcool, the programme staged a new expansion of the cane culture and a boom in distillery construction [P19].

Ethanol was first used as a fuel additive with 20% and 22% blends with regular gasoline. From 1980 onwards it started to be used as a pure fuel on adapted cars. These cars didn't function properly and the automotive industry responded by shifting heavily to pure ethanol powered vehicles. In 1984 almost 95% of the cars produced in Brasil were ethanol powered.

An ethanol powered VW Brisilia from 1980. Click for more.

A ethanol powered VW Brisilia from 1980. Click for more.

In 1985 the oil price dropped and regular gasoline become affordable once again. At the same time the country faced appalling internal inflation and subsidies to the cane industry were eased. By the late 1980s an ethanol supply crisis unfolded. In the 1990s, with the oil industry growing, the programme came near to halt; less than 1% of the cars produced then were ethanol powered.

Now in the dawn of the XXI century, Brasil is one of the few countries on Earth with prospects of growing its oil production, being on the brink of becoming a net oil exporter. Still, the fossil fuel supply constraints elsewhere are breathing new life to the cane industry, whose history is far from over.

Lessons from History

Cane cutters by Fritzner Cedon. Click for more.

Among the things to learn from sugar cane's history, the most positive one is probably its relative success outside the Tropics. On a negative side is its destructive power and non sustainability when cultivated intensively; although the industrial revolution would bring some ease to that.

The plant promises a high energy return on investment, and if successful at higher latitudes can be an important element of world energy stability. But care must be taken, neither Europe nor North America offer the same kind of environment that allows natural cane growth in Brasil, the Caribbean or Indonesia. At least irrigation is a factor reducing energy returns, to be considered at higher latitudes.

One other aspect not to oversee is the cane culture high reliance on hand labour. Despite advances in mechanization, the cane harvest is still widely made by hand, hence its survival in low wage countries. If sugar cane is set to come back to wealthier nations, this issue has to be addressed.

The End

The sugar cane industry that formed in the XVI century was, by its geographic, economic and social size, something unprecedented, which would only find parallel in the Whaling and Coal industries of the XIX century.

While during its migration from the Pacific to the Indic and the Mediterranean sugar cane kept a background role, in its migration to the Atlantic sugar cane assumed the dominant role in economy and society. Sugar cane triggered an unprecedented environmental disruption and provoked the largest migratory phenomenon at the global scale, with the enslaving of millions of Africans. For these reasons sugar cane can be regarded as one of the most important cultures in our Civilization.

Is sugar cane on the brink of making History once more?

Luís de Sousa

The Oil Drum : Europe

Resources

Sugarcane History at UNICA - São Paulo Sugarcane Agroindustry Union.

Sugarcane (in portuguese).

History of Sugarcane and the Environment by Alberto Vieira (in portuguese).

Sugar at Wikipedia.

Previously in The Oil Drum: Report: Brazilian Ethanol is Sustainable.