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Technological Change and Commodity Frontiers in the Yucatán Peninsula, c.1850s-1940s

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Introduction.

The transformative power of new technologies has become something of a cliché. Technological change has served to explain everything from industrial revolutions to political regimes, from cultural values to social structures. It has been noted that technology has been a major historical driver of environmental transformations through, for example, natural recourses exploitation. After all, new tools, machines and practices have determined many of the patterns of commodity production, as the well-known histories of silver, sugar, oil and rubber demonstrate. At the same time, the processes of technological-driven industrialisation in some parts of the world have often been connected to the commodity frontier-making process in far-flung locations. Of course, the interconnections between technological change and expanded commodity production have been diverse and uneven throughout history. It seems evident that the interplay between technological change and commodity production has been specific to material and historical conditions, including such factors as state and imperial politics, geography and the environment.

This article considers the evolution of natural resource frontiers in the Caribbean from the perspective of the history of technology —specifically the changing relations between technological change and the life cycles of commodities between the mid-nineteenth century and the Second World War. Drawing on the cases of three basic resources produced in the Maya-populated Yucatán peninsula —logwood, henequen and chicle— it offers an account of the rise and decline of global commodities. The article contends that the shifting trends of production, trade and consumption of these raw materials were primarily determined by the historical interplay of global technologies, local knowledge and practices, and environmental conditions of production.

In adopting such a technological-historical vision over a long time frame, this article seeks to appraise the technological imperatives for tropical commodity production through a comparative study. The purpose is to understand how technological forces shaped commodity production in the Yucatán peninsula, illuminating common patterns and contrasting certain features and distinctions. Rather than attempting a comprehensive coverage of all the dimensions of logwood, chicle and henequen commodity chains, this article pursues a deeper understanding of the links and co-evolution of global industries and shifting commodity frontiers in the context of the consolidation of industrial capitalism. Such a perspective also exposes industrial imperatives, mutual impacts, political confrontations, transnational networks and unintended consequences.

The economic and socio-cultural history of henequen, chicle and logwood have received considerable scholarly attention. Despite this literature —often confined to area studies— the consideration of these commodities' technological dimensions within a comparative framework has not been given the attention it deserves. Rural communities in Central America and the Caribbean, particularly Maya people in the remote peninsula of Yucatán, have produced and used these natural resources for centuries. It was not until the second part of the nineteenth century — the heart of the so-called Second Industrial Revolution — that the exploitation and manufacturing

of these basic natural resources peaked as they became basic supplies for the growing chemical, agrochemical, pharmaceutical and food industries in Western Europe and the United States. At this point, Maya peoples and global industries became inextricably linked and their histories entangled until well into the twentieth century.

Frontier capitalism and consumer demand during this period were closely related, but such a link cannot be understood without considering how they were mediated by technological and environmental imperatives. In the three cases under consideration, technological changes in industrial and agricultural production significantly transformed the patterns of commodity production throughout the nineteenth century. Technological transformations also played a relevant part, though ambivalent, in their eventual decline in the twentieth century, through the development of artificial substitutes, such as chemical colourants, artificial fibres and gum bases made of synthetic polymers such as resins and waxes. Today, the production of henequen, chicle and logwood are no longer the main economic activities in the Yucatán peninsula, even though cordage, chewing gum and dyestuffs are still traded in large quantities in international markets.

After this introduction, this article consists of three additional sections. The first section discusses the historical impact of technology on the dynamics of tropical commodities extraction, building on conceptual categories such as 'technological frame', 'frontier capitalism' and 'commodity chain'. It considers not only the commodification of nature and the production of raw materials for world markets but also the impacts on social and labour relations at commodity frontiers. The second section traces the global rise, and eventual decline, of the henequen, chicle and logwood commodity chains. It reconstructs and analyses the long-term technological patterns of their extraction at different scales, identifying the specific technologies and expert knowledge involved in their production, including local agricultural and forestry practices. Additionally, it considers the later development of chemical innovations for the industrial production of foodstuffs, dyes and plastics in Europe and North America, particularly the development of mechanical innovations for processing and chemical substitutes. The final section of the article reflects on the interrelated trajectories of technological frontiers and the conjunctures of commodity production from a broader comparative perspective, looking beyond national historiographies and political events to illuminate long-term patterns.

Technology, Commodities and Frontier Capitalism.

There is compelling historical evidence to argue that technological innovations have been a source of profound socio-cultural changes at distinct scales, from the local to the global. As sociologist Stephen Hill has noted, the establishment of a new 'technological frame' throughout a given society pushes the realignment of its culture. In that sense, technological change is a double-edged sword: serving as a source of opportunities and economic change but also bringing about the relocation — even the subordination or destruction — of prevailing cultures.[1] The cultural impacts of technological change are apparent when we consider the extraction of raw materials at the peripheries of the world economy. The capitalist penetration into tropical lands often results in the transformation of indigenous cultures, the weakening of local economic systems and the deterioration of social structures, introducing previously unknown dependencies on the international economy.

A fertile point of departure for understanding the relationship between technology, culture and commodities is the notion of 'frontier'. The apprehension of the dynamics at the commodity frontier as a specific place of transition requires attention to its flexible nature and its interrelation with capitalist spatial expansion. The process of frontier expansion in tropical areas is often driven by commercial and industrial demands in far-flung industrial and urban localities. The dynamics

of the incorporation of previously uncommodified land occurs alongside technological changes that increase the demand for raw materials such as agricultural and forestry products. At the same time, the possibilities presented by the extraction of specific natural resources are constrained by geographic, geological and environmental conditions that in turn influence the patterns of technological innovation in commodity extraction and production.[2] The appropriation and commodification of nature relied, in the words of Jason Moore, on 'an ingenious combination of technology and frontier-making'.[3] For example, Dale Tomich has shown that technological and environmental forces restructured the labour regimes that were prevailing at Caribbean frontiers of sugarcane production during the nineteenth century. From this perspective, nature is recreated through technologies and expertise, which in turn are bound to socio-economic conditions.[4]

Commodity frontiers are more than boundaries marked by nature. Historically, capitalist expansion to previously uncommodified lands has created zones of socio-political and cultural encounters.[5] Therefore, the study of extractive frontiers is also useful for unpacking the historical process of incorporating new peoples to empires, nations and the world economy. A clear historical example is the commercial exploitation of tropical rainforests, which became borders of contact between colonisers and indigenous people.[6] Exogenous and indigenous technological cultures and epistemologies also met at shifting commodity frontiers, which were not physically fixed but fluid. Commodity frontiers are historically constructed spaces of interaction where socio-political and economic structures of tropical rural societies are reconfigured, particularly labour relations and land tenure. Concentrating on the process at work at commodity frontiers, historical anthropologists such as Scott Cook and Eric Wolf have shown that the commodification of Central American and Caribbean natural resources radically transformed indigenous cultures, economies and epistemologies, often involving exploitations and dependencies.[7] This process was not an exception of this region, but a general historical trend of global capitalist development.

The political ecology of commodity frontiers is often related to exogenous industrial and technological changes. For instance, historian Ian Inkster has shown how global chemical advancements and the development of the celluloid industry in England directly impacted colonial dynamics and the politics of warfare in the tropical forests of Taiwan between the 1860s and the First World War.[8] According to Inkster, the exploitation of Taiwanese camphor trees was a pervasive unintended source of marginalisation and conflict of Tayal indigenous communities. Another example would be the resistance from indigenous people in the Spanish Philippines to the expansion of mechanised sugar plantations during the second half of the nineteenth century. As environmental historian Richard Tucker shows, land-grabbing and commercial agriculture politicised the indigenous frontier at the Philippine island of Negros to the point that warfare broke out on the island and its tropical forests were decimated.[9] For the case of Latin America, there are many other exemplary cases, most notably the expansion of rubber and palm oil frontiers in the Amazon.

Also central to this article is the analytical category of 'commodity chain', understood as an underlying socioeconomic structure of modern global capitalism. The category of commodity chain – often also called 'value chain' or 'production network' – is widely used among political economists and economic historians to shed light on the entangled processes of extraction, transportation, production, commercialisation and consumption of commodities. Commodity chains are fluid material and knowledge-based circuits, where some links can concentrate the power of the whole chain through, for example, the control of prices and production quotas. Using this category of commodity chain, economic historians such as Carlos Marichal, Steven Topik and William Clarence-Smith, among others, have shown how specific agricultural raw materials — from coffee to cotton, from rubber to sugar— were basic inputs for European and US industries and foodstuffs in their mass consumption markets during the nineteenth and twentieth centuries.[10]

It seems clear that the ever-increasing widespread global consumption of Latin American raw materials that emerged in the nineteenth century was the driving force behind frontier extractivism in the region. What remains a disputed question among economic historians is whether commodity monoculture and the unequal terms of the exchange of commodities have been prime factors behind Latin America's relative underdevelopment.[11]

A technological history of frontier capitalism needs to concentrate on local-global articulations. During the second half of the nineteenth century, the penetration of commodity frontiers went hand in hand with the consolidation of manifold global structures, systems and institutions, which together transformed the scale and scope of tropical agricultural production.[12] These global structures were not only political (e.g. empires) but also socio-environmental, technological and economic. A good example is patent systems, but there are many others, from transnational transport networks to international capital markets. Again, these global structures not only impacted local frontiers but were themselves shaped by local conditions. There is, of course, a temptation to narrate a unified history of global commodities vis-à-vis global technological changes. A more rewarding approach is to rewrite the local, national and regional histories of commodities with an emphasis on their technological dimension, including world connections, exchanges and dependencies.

One valuable lesson to be drawn from recent works examining the history of global commodities through the lens of the history of science and technology is that any global history of commodities first requires a close examination of local technologies-in-use, indigenous knowledge systems and hybrid or creole practices, including the impact of chemical and mechanical transformations on the production of cash crops.[13] This approach requires an understanding of technology in its broadest sense, including its more informal forms, such as practical, tacit, hybrid and creole. It not only requires consideration of technology as an object (e.g. an artefact), but to related issues such as the practices, actors, spaces and institutions of knowledge production, circulation, appropriation and contestation. Another important reason to adopt a broad definition of technology is to transcend the artificial division between technology and the environment and instead look at the interplay between the two.[14] Such an approach to the history of technology may help open up the study to include actors and societies that have been less visible or even marginal in the history of technology, such as indigenous communities and local peasantry in tropical agricultural and forest frontiers.

Several factors have been the historical drivers of commodity booms and busts. The patterns of the production, trade and consumption of Latin American commodities can be correlated with fiscal, financial, consumption and trade-related matters. Technological transformations have also been a major force of the life cycle of commodities. Intersecting circuits of technologies and expertise developed in tandem with the making of these global commodity chains, thereby facilitating their production, trade and consumption. This is especially clear for the years of the so-called Latin American export boom (c. 1880-1929), which were characterised by accelerated international trade, new imperialism, knowledge globalisation and cultural encounters. These decades saw the expansion and diversification of Latin American commodity chains of foodstuffs and basic raw materials. The Great Depression of the 1930s diminished the volume of exports and altered the prices of Latin American commodities, although the international demand for tropical raw materials continued to be remarkable.

The appetite for tropical raw materials followed the industrialisation processes and concomitant technological transformations in Europe and the United States during the years of the so-called Second Industrial Revolution. That was the era associated with technological breakthroughs in mechanics, organic chemistry and telecommunications. The development of international transport networks made of railroads and steamships facilitated global commodity

production and trade. It was also a time of practical scientific research that resulted in, among other things, important advancements in agricultural technologies and processes, which were unplanned spin-offs from other economic sectors (refrigeration, barbed wire, steamship) or new equipment and inputs deliberately conceived for agriculture.[15] Along with botanical and agricultural sciences, an array of mechanical and chemical innovations served as tools for the commodification and standardisation of tropical landscapes. This was not, however, a period characterised solely by global technological breakthroughs but also by the ubiquity of local technologies. Global technological innovations coexisted with a large number of indigenous artefacts and traditional practices, many of which had a central economic and cultural relevance.

One cannot complain that the history of Caribbean commodities is a neglected topic.[16] As many historians have shown, this region has long been an area of domestication and production of a large variety of agricultural products, many of which —like sugar, coffee and cocoa— have been objects of global exchange. The plantation system was grounded in the Caribbean in a context of imperial clashes. In their expansion, plantations met local eco-systems and agricultural fields at the margins of the world economy, creating new areas of contact and conflict. Therefore, a central concern in the study of such Caribbean plantations is the impacts on local farming communities, smallholding agricultural practices, and crops oriented principally toward subsistence and local markets. The exploitation of Caribbean tropical forests was also linked with new imperialist endeavours and the making of industrial capitalism. Forest frontiers sometimes cut across traditional national and imperial borders, resulting in the politicisation of the sites of resource extraction. Of course, crops oriented toward subsistence and local markets — sometimes called anti-commodities — continued to be valuable for Caribbean peoples during the years of the export boom.[17]

A Technological History of Maya Commodity Frontiers.

The peninsula of Yucatán was one of the last frontiers in the Greater Caribbean.[18] The situation of this remote and forgotten land of Maya peoples changed during the second half of the nineteenth century, when the production of raw materials for international markets became widespread in the area. Comprised of three Mexican states (Campeche, Quintana Roo and Yucatán), the colony of British Honduras (today's Belize) and the northern part of Guatemala (Petén), this region was sparsely populated and politically uncontrolled. The Yucatán peninsula was a contested frontier, where colonisation and commodification encountered indigenous communities that resisted political expansion and capitalist extraction. Although it would soon become an area of production of large quantities of commodities for distant markets, local cultivation of maize and other staples — vital for the survival of the Maya population—continued to occur at the margins of large-scale commercial states and rainforests. The Maya way of farming and relationship with nature were very different from those to large monoculture plantations, whose production was limited to a single crop, or massive exploitation of forests. For instance, indigenous communities used the widden farming system — involving the slashing and burning of vegetation— which yielded only enough for self-sufficiency or at most for sale at local markets.[19] This subsistence-style system of agriculture was achieved by means of traditional technology.

During the second part of the nineteenth century and the first decades of the twentieth century, the Yucatán peninsula became the main world-producer of henequen, logwood and chicle. Foreign capital investments and international trade drove the exploitation of these resources. In the words of the historian Hernan W. Konrad, "available natural resources were exploited in a fashion regulated by international demand and the price for primary products".[20] These raw materials were not only object of capitalist development but were native natural resources that had

had a central relevance in the Maya economy and society for centuries. Resource exploitation happened at the expense of local 'campesinos' and their agricultural lands and forests, often involving conflicts with indigenous socio-economic and knowledge structures. Maya workers came to engage in the process of commodification, but not without resistance. It was a response not only to proletarianisation and land dispossession but to marginalisation, violence, displacement, acculturation, the destruction of nature and the expansion of infrastructures. The boom of Yucatecan commodities took place in the midst of the Caste War (1847–1901), a major conflict between the Mexican state and indigenous populations.[21] It was a political conflict with an international dimension. In addition to its economic interests in the region, Britain controlled the southern part of the peninsula. Nationals from other countries such as Spain and the United States became also involved in the conflict.

The rise of henequen, also known as sisal, is the foremost example of Yucatán's transition to agrarian capitalism. [22] During the mid-nineteenth century, sugarcane became the major cash crop of the area but was soon replaced by henequen. A hard cellulosic fibre stripped from a plant native to the Yucatán peninsula, henequen had been used since ancient times by Mayans to make ropes, clothes and mats. Known as *kih* in Maya language, the henequen fibre is obtained by scraping the sword-like leaves of different varieties of agave that were first domesticated in this region for cultivation on commercial plantations. It was during the 1880s, coinciding with the Porfiriato regime, that henequen became the leading export commercial crop of Mexico. [23] From that moment on, labour-intensive large-scale henequen states were built in Yucatán. Mayan communities were pushed to work as wage labourers in henequen states built on the arid lands of the northern part of the peninsula. They became peasant-peons who harvested this fibre crop —a simple task — while continuing to maintain their subsistence farming. The golden age of Yucatecan henequen lasted until the First World War.

Technological change set the stage for the boom of henequen. Agricultural technologies were improved during the final decades of the century, with the objective of saving both labour and time and thereby accelerating grain harvesting on a massive scale. Such agricultural innovations were only made possible by a combination of practical knowledge about both machinery construction and agriculture. For instance, the invention of the reaper-binding machine in the United States in 1872 reduced labour intensity in grain harvesting but demanded large quantities of binder twine. For farmers in the Midwestern United States, henequen fibre offered several advantages. Metal wire was expensive, bulky and a risk for animals. By contrast, henequen was cheap, resistant and could be obtained in large quantities from the Yucatán peninsula. Other commercial uses of henequen were as rope, cordage and rigging cable for a range of manufacturing and commercial activities, such as fishing and shipping.

The perfected twine-knotting machine soon became the most widespread harvesting technology in the vast grain fields of the United States. Several Chicago-based companies, such as McCormick Machinery Harvesting Company, Deering Harvester Company and Plano Manufacturing Company, manufactured reaper-binding machines during the 1880s and 1890s. American commercial houses, such as Thebaud Brothers of New York, also sold machinery and tools to Yucatecan planters. This company also happened to be one of the largest buyers of raw Yucatecan henequen. In 1902, the International Harvester Company was established through a merger of the era's leading manufacturers of agricultural machinery; this company monopolised the American market of mechanical reaper-binders from that point on.

Equally important for the rise of henequen was the mechanisation of its production. As early as in the 1840s, US inventors had tried to mechanise the decortication of henequen in Yucatán, without much success.[24] It was Yucatecan locals who first successfully invented machinery for scraping and processing henequen starting in the 1850s. Some 60 patents were

requested in Mexico for this purpose between 1857 and 1889 as well as other various public prizes awarded to local inventors.[25] Among them, the mechanical rasping called 'Solis wheel' was especially important.[26] During the 1880s and 1890s, successive innovations were devised and manufactured following Yucatecan inventions. Although the defibration machine was a Mexican invention, US and British manufacturers supplied most of the machines used in Yucatán. Other technological equipment, such as henequen presses, were likewise imported.[27]

Each agave leaf only yields a small portion of henequen fibre. On the early henequen haciendas, the separation of the fibre from the pulping matter was done by hand, yielding insufficient cord for exportation. Until the development of mechanised devices, rasping was done using indigenous hand-tools (*Tonkós* and *pashké*). Productivity was low, large quantities of fibre were wasted, and the henequen cord produced was of inconsistent quality, durability, length and weight. Moreover, it was impossible to meet the increasing foreign demand with such a labour-intensive and time-consuming process. As the inventor and carpenter José Esteban Solis, himself declared, before the rasping machine there were not enough workers to make the mass production of henequen profitable.[28]

The improvement and use of decorticating technologies fostered the introduction of new sources of energy. To extract the fibre, planters started using steam-powered spinning rasp machines in the 1860s. In 1892, over 1300 imported steam-powered rasping machines were employed in Yucatán.[29] Steam-engines moving the wheels of the rasping machines required a constant supply of firewood and water until gas and oil were introduced in the 1910s and 1920s.[30] The northern part of the peninsula had hundreds of windmills and animal-operated pumps raising water as well as an extensive network of transport infrastructures moving supplies.

By the turn of the century, fibre-processing technologies were present on most sizeable haciendas —still family-owned— which had machine houses stocking presses, rasping trains, mills, mechanical cleaners, boilers and steam engines. The most modern automatic rasping machines could process around 20,000 leaves per hour.[31] Biological conditions —especially the perishability of agave — gave rise to the development of agroindustrial complexes in henequen fields. Agave leaves dry fast, and therefore the pulp had to be removed within a day after harvesting. Processing had to be done on the plantation or at a nearby location. An endless conveyor separated the henequen fields and the processing factory. As in the modern sugarcane factories established throughout the Caribbean region, work on the plantation fields and the machine house had to be accurately synchronised in time and space. It seems, however, that the coordination between field and factory was not as efficient as in the most advanced sugarcane complexes.[32] The rise of mechanised henequen production also fostered the establishment of a local machine and tools industry in Yucatán that, although small and intensive in labour, had the capacity to maintain and repair the equipment and provide spare parts.[33]

In contrast to processing techniques, innovations in henequen cultivation and harvesting were very limited and continued to be labour-intensive activities. The dry Yucatecan plains and the climate of the north of the peninsula were perfect for henequen cultivation. There was no need to plough the land or use pesticides or fertilisers. Henequen plants lived between 15 to 20 years, at which point they had to be replaced. From the time the plant was 6 or 7 years old , the large agave leaves were cut using machetes during the dry season — that is, between November to May. The leaves were transported by carts and then brought to the factory through a mechanical belt. After the fibre was mechanically extracted by decortication, it was washed and hung upon lines for drying under the sun. Large henequen haciendas had warehouses to store the baled fibres of dried henequen.[34]

The henequen complex induced the expansion of a modern transportation and communication infrastructure in the area.[35] In the 1880s and 1890s, this included railways, roads,

steamships, telegraph lines, telephones and wharves. Infrastructures networks were needed for the export of raw henequen fibre. The railway infrastructure connected the main cities in the henequen region (such as Merida) with the harbours of Sisal and Progreso. In addition, large commercial haciendas had portable narrow gauge tramways to ship henequen from the states to the railway stations. Portable Decauville tracks drawn by mules extended through the fields to load the bulk agave leaves and wood necessary for steam engines.

Yucatán specialised in the export of raw fibre. The final manufacturing of henequen products was rare in Yucatán; for the most part, local states only accomplished the primary processing. Most of the final manufacturing of henequen into commercial twine and cordage was done in America factories, similar to those of the cotton industry. Cordage manufacturing companies in the United States— such as Plymouth Cordage Company in Massachusetts — had automatic twine spinning machines.[36] Some cordage plants were built in Yucatán during the late nineteenth and early twentieth centuries but were ultimately unsuccessful. Later, in the mid-1920s, cordage factories producing rope and binding twine were established in the city of Merida, supplying national and international markets. However, they only represented a small share of the market. The cordage-making technology was relatively simple, which meant that some of the machinery and equipment could be designed and produced locally.

By the First World War, Yucatán was a world leader in the international market for hard fibres, supplying more than 85% of the US demand for binder twine.[37] This explains why sisal was, at the international level, one of the few leaf fibres whose production was automatised.[38] However, during the interwar period, the henequen industry entered a depression, and Yucatán lost its world primacy. The main competition came from alternative sources of twine and rope, such as Manila hemp from the Philippines and jute produced in India.[39] The competition also came from other parts of the world such as Java, Cuba, Kenia, Dutch Indies and Brazil, where sisal was naturalised. In some of these countries, hybrid sisal plants yielded a higher quantity and more resistant fibres after fewer years of cultivation.

The gradual transition in US grain fields, during the 1920s, from the binder machine to the combined harvester also reduced the demand for binder twine.[40] Although the invention of the hay-baler in 1937 would give a second life to henequen during the 1940s, given an increased need for baler twine, the replacement of henequen was inevitable. The gradual development of cheaper and more resistant synthetic fibres after the Second World War — made of nylon, dacron and polyethene— only solidified the decline of henequen.[41] Another important factor behind the decline of henequen was that it could not be supplied on demand, as the plant needed to be cultivated for several years before it yielded fibre. Another aspect triggering the crisis of the industry (which needs further investigation) was the increasing inefficiency and low quality of production. It seems that the mechanical obsolescence of Yucatecan rasping machines was not unusual, with regular breakdowns due to lack of maintenance. This resulted in foreign complains about the quality and thickness of Mexican henequen. There were also criticisms about the traces of other materials in Mexican henequen in comparison with the hard fibres produced elsewhere.[42]

In a parallel history to henequen, the dynamics at the rainforest frontiers of the Yucatán peninsula were likewise defined mainly by technological changes on various scales. However, traditional forestall forms of commodity production and technological imperatives were very different from those of the henequen-producing states.[43] Forest endowments were given and fixed, yet technology transforms them into commodities that were traded in international markets. Gum- and colourant- producing trees were found in significant quantities in the southern lowlands of the Yucatán peninsula. This tropical rainforest area contains a wide range of other trees such as cedars, mahoganies and strangler figs. The specific extraction and processing techniques that could be used were determined by the biological characteristics of the trees themselves.

The extraction of forest resources — particularly chicle, logwood and exotic hardwoods — drove infrastructures to access southern parts of the peninsula of Yucatán. The expansion of the frontier of forestry extraction required further penetration into the heart of Maya territory, which was still controlled by indigenous peoples. Railroads, roads and ports became key means of exporting chicle to the United States. With the boom of the American chewing gum industry during the first decades of the twentieth century, tractors and carts arrived in the forest and isolated indigenous villages of the southern part of Yucatán peninsula. Chicle stations in the tropical forest were thus connected with Yucatecan cities and ports (and later on with airports financed by chewing gum companies) from where large quantities of raw chicle were exported to the United States. The American anthropologist Cyrus L. Lundell explained this situation on an ethnobotanic trip to the southern Mexican state of Campeche in 1931: 'The exploitation of the sapodilla forest has made the remote interior accessible. Road and trails have been opened to bring out chicle by truck and mule-trains'.[44] Lundell also worked for the Tropical Plant Research Foundation, a US institution that carried out botanical research on chicle production in the Caribbean and Central America between 1927 and 1931.

Between the 1870s and 1940s, Yucatecan chicle became the world's main source of chewing gum production.[45] The ever-increasing expansion of chicle extraction in Caribbean forests followed the boom of chewing gum consumption in the United States during those years. Mechanical and chemical improvements were the backbone of the growing chewing-gum industry. In 1871, the Brooklyn inventor Thomas Adams was granted a US patent for a gum manufacturing machine that required natural chicle as an essential ingredient. Before Adams's patent, chewing gum was made largely of sugary paraffin wax —invented in the 1840s—and was already a relative commercial success in the United States. However, Adams realised that natural Maya chicle was far superior, thus driving a paradoxical transition from a chemical to a natural product source. Adam's gum-making machine was further improved during the following decades, and different flavours were added to the final product. Chewing-gum manufacturing would become a business success from the late nineteenth-century, as the cases of the large American companies Wrigley and Adams make clear.

Chicle (known as *sicte* by Maya people and as *tziktli* in Nahuatl) was the basis for the rise of the American chewing gum industry. A type of natural latex, similar to rubber, chicle was obtained from the sapodilla evergreen tree (*manilkara zapota* or *zapotilla*), abundant in the forests of the Yucatán peninsula.[46] Maya techniques and practices of chicle extraction in Yucatecan sapodilla forests did not change during the chewing gum boom. Tapping incisions to the living tree were made using machetes during the rainy season (June-February), allowing the sapodilla tree to exude its liquid latex. This was a labour-intensive process that relied on traditional practical knowledge and expertise. The necessary tools used by tappers were often provided by intermediary contractors who supplied chicle to foreign chewing gum manufacturing companies.[47] Extraction was not only constrained by the age and distribution of the trees —often irregular and spread over a vast territory— but also by ecological conditions. Each tree could only be tapped every three or four years through diagonal cuts on the bark of the tree. The exuded latex was boiled at forest camps, reducing its moisture and thickening it. Then the crude sticky latex was poured into wooden molds to form chicle blocks.

Although chicle was extracted from other parts of Central America, such as the Miskito coast of Nicaragua, the US chewing gum industry mostly relied upon the local communities of the Yucatán peninsula, which almost had a world monopoly on the supply of chicle. In contrast with the case of henequen, indigenous communities and other migrant workers were ultimately independent seasonal labourers, although they were often tied to contractors, landowners, cooperatives or concessionary companies.[48] Companies that received forest concessions in the area

during the late nineteenth and earlier twentieth centuries included the Mexican Exploration Company and the East Coast of Yucatán Colonization Company.

American chewing gum companies bought crude chicle in blocks of varying consistency, moisture and quality, with prices varying accordingly. Final standardised chewing gum was mass-manufactured in the United States, where chicle was washed, dried, centrifuged and heated at high temperatures. Sheeting and wrapping machines were used to cut and pack the final product. Finished chewing gum sticks consisted of usually no more than 10% of pure natural chicle; the remainder consisted of various ingredients, including synthetic gums, flavours and above all sweeteners such as sugar or syrups. [49] US chewing gum manufacturers increasingly relied on modern laboratory science and industrial research to produce a consistent and sterile product. For instance, the chemist Frederic Dannerth, lead researcher of the Rubber Trade Laboratory in Newark (New Jersey), noted at an April 1917 meeting of The American Chemical Society that, due to the growing importance of the US chewing gum industry, it had 'become necessary to establish standard methods for the purchase of the crude block chicle'.[50] To meet these standards — after cleaning the chicle of dirt, leaves and bark — manufacturers had to assess four factors: moisture, colour, quality and volume. Similarly to henequen primary processing at the plantation site, latex-gatherers (*chicleros*) accomplished a basic in-situ refining through which they obtained an intermediate product (chicle) that was somewhere between exuded latex and chewing gum.[51] Mexico would not manufacture commercial chewing gum until the 1920s.[52]

After a decline during the Great Depression, chewing gum consumption peaked in the United States during the early 1940s. In 1940, 80% of the chicle consumed in the United States came from the Yucatán peninsula, with the state of Campeche contributing over 50% of total production.[53] Chicle was in short supply after the Second World War, a circumstance that hindered its further commercial expansion. The spatial distribution and ecological conditions of sapodilla trees not only shaped the production process but constrained the size of the industry. These trees could not be yet cultivated on plantations and had not been naturalised to other regions. Yucatecan sources were becoming less abundant and more difficult to access.[54] Also, chicle extraction was seasonal; trees' latex vessels lay dry for long periods after tapping; and supply was heavily dependent on local labour, which retained the task of tapping the trees and preparing the raw blocks. Such environmental and labour limits, together with the exhaustion of the sapodilla trees, drove the development of synthetic substitutes during the post-war era. In the end, the fortune of the local chicle economy was decided by international forces. Again a chemical innovation was behind the patterns of commodity production, but the entanglement between technological changes and the dynamics at chicle frontiers were neither linear nor inevitable. The transition from a natural gum base to bases derived from synthetics was increasingly a reality by the late 1940s. This resulted in a sharp decline in the demand for natural chicle. Industrial chemistry opened and closed the cycle of chicle extraction in the forests of Yucatán, Belize and Petén, directly impacting the socio-economic and labour structures of indigenous people and triggering the politicisation of Maya frontiers and decades of local conflict.

The third commodity this article considers is logwood (*haematoxylum campechianum*), a tree known as *ek'* by the Maya —which has properties similar to those of brazilwood— and grows near rivers and bays. From prehispanic times, Mayas used this strong wood for construction and its extract, obtained from the heartwood, as a dye and medicine. Beginning in the late sixteenth century, logwood was exported to Europe in large quantities along with other natural colourants produced in the Caribbean and Central America such as indigo, madder and cochineal. Used with mordants such as copper, logwood yields black, purple, yellow and blue dyes valuable for colouring and printing textiles. Historically the most significant areas for the commercial exploitation of logwood trees in the Yucatán peninsula have been the banks of the River Hondo,

in the southern border between Mexico and Belize, and the New River in Belize (then the colony of British Honduras) as well as the forests of Laguna de Términos in the southern Mexican state of Campeche.[55] Logwood cutting was a central factor behind the colonisation of British Honduras, sparkling political clashes between the Spanish and British empires to control its regular supply. During the nineteenth century, logwood trees were naturalised to other parts of the world, including Asia and the United States but particularly other places in the Greater Caribbean such as Jamaica, Cuba and Haiti, where it was exploited on plantations. [56] Although logwood cutting and trade declined somewhat in the British colonial outpost of Belize during the late nineteenth century, it increased in other places, including Jamaica and the Mexican state of Campeche, during the second part of the nineteenth century.[57] For instance, in 1892 The West Indies Chemical Works Ltd., a manufacturing company that went to supply logwood extracts and crystals to international markets for over half a century, was established in Spanish Town, Jamaica.[58]

Nineteenth-century industrialisation processes — particularly the mechanisation of the textile industries— in Britain, France, Germany and the United States intensified the Atlantic trade of logwood extracted from rainforests in the Maya region. As in the cases of henequen and chicle, technological changes in Europe and the United States explain the quest for logwood, with long-term implications for the exploitation of peoples and environments in the remote forests of the Yucatán peninsula. During the Caste War, Maya refugees were pushed into tropical forests, where they worked in logwood and chicle extraction but also on sugar states in newly cleared lands.[59] The deep red extract obtained from logwood had various additional uses in European and American industries, such as the papermaking, printing, chemical and pharmaceutical sectors. Its primary use was as a colourant to dye cotton, wool, paper and crystals, but it was also a basic raw material in the large-scale manufacturing of ink. Hematein, which results from the oxidation, by either natural or artificial means, of logwood extract, also had important uses. By the turn of the century, hematein, in its purified form, started to be used as a routine histological stain for microscopy in laboratories. Although the extract of logwood (haematoxylin) was first successfully used as a biological staining formulation in 1865, it was not until the 1920s that researchers began to realise its full value.[60]

As in the cases of henequen and chicle, new transport and communication infrastructures penetrating indigenous lands proved a critical factor in the colonisation of the forest and the expansion of logwood extraction, although limited by the sabotage of Maya rebels. Logwood cutting was done manually using hand-tools, mainly axes and saws. Then, the bark was removed in-situ, and the logs cleaned and squared into smaller pieces. To reduce costs, from the mid-nineteenth century, it became common to isolate the logwood extract by mechanical means rather that exporting the raw log, thereby reducing the shipping expenses. Cutting logwood was more expensive than tapping chicle, which may explain the shift to chicle extraction in the area during the first decades of the twentieth century. As in the case of chicle, forest concessions for the exploitation of logwood were granted by the Mexican federal government to both Mexican and foreign companies.

A good example is the Mexican company Cuyo & Anexas, established in 1876 in the northeastern part of the Yucatán peninsula with the backing of German capital investment. This firm set up a large company town that exploited forestry resources including logwood and chicle. It had a narrow-gauge railroad, a telephone network, large warehouses and a company pier.[61] In 1895, however, German investors withdrew as artificial dyes were becoming cheaper and more reliable than the exploitation and transport of logwood extracts to Europe.[62] As in the case of chicle, most probably overproduction was also a constraining factor, as logwood was less accessible than other tropical trees. A few years earlier, in 1892, a company called the Mexican Exploration Company, backed by British capital, had been created to exploit Yucatecan forest

products. Another example was the Compañia Colonizadora de la Costa Oriental de Yucatán, which produced large quantities of both chicle and logwood.

Synthetic dye chemistry opened a new technological paradigm in the textile industry. The first synthetic dye had been invented in England back in 1856 by chemist and businessman William Henry Perkin. From then on, and throughout the later nineteenth century, artificial dyes would be invented in the context of routine industrial research, predominantly in the German chemical sector. German dyestuff companies would, from the 1880s, employ large numbers of trained chemists and engineers. Chemical companies protected their invention through both patents and trade secrets.[63] In 1869 alizarin was synthesized and in the 1880s synthetic indigo. The first commercial fast synthetic black dye was invented in 1862 in Manchester by the German chemist Heinrich Caro, who worked for the chemical manufacturer Roberts, Dale & Co.[64] Following this invention, additional synthetic black dyes obtained from coal-tared hydrocarbons were made commercially available, such as John Lightfoot's black process, which was applied to cotton fabrics.

The invention of aniline dyes did not immediately displace logwood and madder from the international market of colourants. The transition from natural colourants to synthetic dyestuffs was a long process that took over half a century. In a context of growing but volatile international markets for colourants, logwood coexisted with artificial dyes. During their early years, the costs of producing the new synthetic dyes continued to be high. The artificial dyes did not allow for the same range of colours and shades as natural logwood. Natural dyes were sometimes used together with synthetic ones.[65] Dying processes in textile manufacturing remained complex, requiring the collaboration of experts in industrial chemistry and colourists with practical experience in natural colourants. Mordants still needed to be used with precision to obtain particular shades. Similarly, as occurred with indigo, logwood extracts kept the capacity to compete for international markets, as they were exported in large quantities to Europe — notably France and Britain— during the late nineteenth and early twentieth centuries.[66] Innovations in synthetic dye manufacturing and testing also had direct applications to natural colourants and mordants, reducing costs and improving the consistency of natural dyes.[67] The synthetic dye industry had emerged in the late nineteenth century, the same period during which logwood began a second life, which lasted through the First World War. For example, the port of El Carmen, in Campeche, had enjoyed a golden period of logwood trade during the decade of the 1890s, when it exported to the United States, United Kingdom, Germany and France. The decline of logwood extraction in the Yucatán peninsula had to wait until the decade of the 1910s.[68] Logwood exports stopped to be of commercial and industrial importance in the textile industry during the 1920s. By then, aniline dyes were already cheaper, readily available in large quantities and easy to use.

From technological trajectories to commodified nature and culture.

The history of technology explains major changes in the geographies of capitalist development. This article highlights how the interplay of global technological changes and local technologies and practices allows for large-scale extractive forms of production of tropical resources. This technological view of commodity extraction provides a number of insights for a connected history of global industries and resource frontiers. Indeed, a comparative analysis of commodity chains could help us rethink the ways in which global technological changes, indigenous knowledge and local practices were intertwined with a rise in the production of export commodities between the mid-nineteenth century and the Second World War. Technological trajectories affecting commodity production were the result of several political-institutional factors such as the appropriation of knowledge through patents, the development of standardised technological

cultures and local responses to the exploitation of these natural resources. Factors limiting the extraction of these resources also affected global innovation in the context of a rise in the professionalisation of research at industries and multinational companies.

Looking at just the cases of logwood, henequen and chicle, it can reasonably be argued that, from a long-term perspective, mechanical and chemical innovations served as the primary driving force behind rural transformations in the Yucatán peninsula. These transformations were not only the result of the introduction of new processing devices but also of new infrastructures and logistical capacities along the commodity chain. Yet it was not only distant trajectories of technological change that drove the cycles of exploitation of Yucatecan forests and agricultural lands. In defiance of technological determinism, local machinery and practices of commodity extraction in the Yucatán peninsula simultaneously pushed global technological innovations and a quest for synthetic substitutes. This is especially clear for the case of the henequen-wheat complex, which was characterised by a mutual dependence and synchrony between the technologies of grain harvesting in the United States and the mechanised henequen states in Yucatán.

What is paradoxical is that technological changes were bound to ecological conditions. Overexploitation and the increasing difficulty of accessing forestry products drove a quest for alternative sources of supply. The development of synthetic substitutes eventually led global industries to lose their interest in Yucatecan materials. For many years natural and synthetic substitutes competed and coexisted in international markets, although the dependency on natural commodities was in the long run broken by the development of a global program of chemical innovations for the production of foodstuffs, fibres, dyes, stains and plastics. The abandonment of these resource frontiers brought about a crisis of extractive economies in the Yucatán peninsula, which were highly dependent on foreign markets and industries.

The impact of the ‘technological frame' was, however, not immutable, nor did it inevitably determine the fate of natural, political or human frontiers. Technological change may explain major discontinuities at frontiers of extraction, but it did so differently in each case, with distinctive paths, variable chronologies and unintended consequences. The ways in which new chemical, refining and processing techniques influenced the exploitation of natural resources in the Yucatán peninsula followed multiple paths. The interplay between technology and commodities was neither linear nor straightaway but was instead bound to geographical and environmental conditions. Henequen, chicle and logwood possessed very different intrinsic physical and biological properties. Extractive and cultivation practices, refining techniques and manufacturing processes varied from one commodity to the other. Labour systems also varied, from the hacienda regimes of henequen plantations to seasonal indigenous work in tropical forests.

During the years of the so-called Second Industrial Revolution, commodity frontiers in the Yucatán peninsula became deeply entwined with industries and mass markets in western Europe and the United States. It was a ‘dissonant connectivity’, to use Ian Inkster’s eloquent words.[69] The frontiers of extraction, manufacturing and consumption of these commodities were separated, that is, nature, industries and the market had different socioeconomic conjunctures. The commodification of Yucatecan lands and forests also reorganised indigenous agrarian socio-economic systems and the social relations of rural communities. This is especially clear if we look at the international division of labour in the production of these commodities. Maya peoples were necessary workers for the production of these commodities and, although they were not slaves, they suffered exploitative conditions. However, indigenous communities were not passive actors. The pressure to produce vast quantities for mass markets triggered the politicisation of commodity frontiers and indigenous resistance to the introduction of new technologies such as railroads, telegraphs and steam-machines.[70] In fighting the new mode of production, the Maya people were ultimately resisting the extinction of their culture.

[1] Stephen Hill, *The Tragedy of Technology: Human Liberation versus Domination in the Late Twentieth Century* (London, Pluto Press, 1988).
[2] Dale Tomich, 'Commodity Frontiers, Spatial Economy, and Technological Innovation in the Caribbean Sugar Industry, 1783–1878', in Adrian B. Leonard and David Pretel (eds.), *The Caribbean and the Atlantic World Economy*: Circuits of Trade Money and Knowledge, 1650-1914 (London: Cambridge Imperial and Post-Colonial Studies Series, Palgrave Macmillan, 2015):184-216.
[3] Jason W. Moore, *Capitalism in the Web of Life: Ecology and the Accumulation of Capital* (London and New York: Verso, 2015): 129. On the impact of technological changes on natural resource exploitation see also pages 155-161.
[4] Tomich, *Commodity Frontiers*.
[5] Michael R. Redclift: *Frontiers: Histories of Civil Society and Nature* (Cambridge, MA: MIT University Press, 2006): Chapter 2.
[6] See, for example, Christopher R. Boyer, *Political Landscapes: Forests, Conservation, and Community in Mexico* (Durham: Duke University Press 2015); Eric R. Wolf, *Europe and the People Without History* (Berkeley and Los Angeles: University of California Press, 1982); Catherine LeGrand, *Frontier Expansion and Peasant Protest in Colombia, 1850–1936* (Albuquerque: University of New Mexico Press, 1986); Martin Daunton and Rick Halperin (eds.), *Empire and Others British Encounters with Indigenous Peoples, 1600-1850* (Philadelphia: University of Pennsylvania Press, 1999); Claudia Leal, *Landscapes of Freedom* (Tucson: The University of Arizona Press, 2018).
[7] Scott Cook, *Understanding Commodity Cultures: Exploration in Economic Anthropology with Case Studies of Mexico* (Maryland: Rowman & Littlefield Publishers, 2004); Eric R. Wolf, 'Types of Latin American Peasantry: A Preliminary Discussion', *American Anthropologist* 57, no. 3 (1955): 452–471.
[8] Ian Inkster, 'Indigenous Resistance and the Technological Imperative: From Chemistry in Birmingham to Camphor Wars in Formosa, 1860s–1914', in David Pretel and Lino Camprubí (eds.), *Technology and Globalisation: Networks of Experts in World History* (London: Palgrave-Studies in Economic History, 2018): 41-74.
[9] Richard P. Tucker, *Insatiable Appetite: The United States and the Ecological Degradation of the Tropical World* (Berkeley: University of California Press., 2002): 101-3.
[10] Steven C. Topik and Allen Wells, *The Second Conquest of Latin America, 1850-1930: Coffee, Henequen and Oil* (Austin: University of Texas Press, 1997); Steven Topik, Carlos Marichal and Zephyr Frank (eds.), *From Silver to Cocaine: Latin American Commodity Chains and the Building of the World Economy, 1500-2000* (Durham and London: Duke University Press, 2006); William Clarence-Smith and Steven Topik (eds.), *The Global Coffee Economy in Africa, Asia and Latin America, 1500-1989* (Cambridge: Cambridge University Press, 2003).
[11] Sandra Kuntz-Ficker (ed.), *The First Export Era Revisited Reassessing its Contribution to Latin American Economies* (London: Palgrave Studies in Economic History, 2017).
[12] Jonathan Curry-Machado (ed.), *Global Histories, Imperial Commodities, Local Interactions* (Basingstoke and New York: Palgrave-Macmillan, Cambridge Imperial and Post-Colonial Studies Series, 2013).
[13] Lisa Roberts (ed.), 'Special Issue: Exploring global history through the lens of the history of chemistry', *History of Science*, Volume 54 Issue 4 (2016); Daniel Rood, *The Re-invention of Atlantic Slavery: Technology, Labor, Race, and Capitalism in the Greater Caribbean* (Oxford University Press, 2016); Francesca Bray, Peter A. Coclanis, Edda L. Fields-Black and Dagmar Schäfer (eds.), *Rice: Global Networks and New Histories* (Cambridge: Cambridge University Press, 2017).
[14] Martin Reuss and Stephen H. Cutcliffe (eds.), *The Illusory Boundary: Environment and Technology in History* (Charlottesville: University of Virginia Press, 2010)
[15] Ian Inkster, *Science and Technology in History: an Approach to Industrial Development* (Basingstoke and London, Macmillan 1991).
[16] See, for example, Sidney Mintz, *Sweetness and Power: The Place of Sugar in Modern History* (New York: Penguin Books, 1985); Stuart McCook, *States of Nature: Science, Agriculture, and Environment in the Spanish Caribbean, 1760-1940* (University of Texas Press, 2002); Victor Bulmer-Thomas, *The Economic History of the Caribbean Since the Napoleonic Wars* (Cambridge: Cambridge University Press, 2012); Adrian Leonard and David Pretel (eds.), *The Caribbean and the Atlantic World Economy: Circuits of Trade, Money and Knowledge, 1650-1914* (Basingstoke and London: Palgrave-Macmillan, Cambridge Imperial and Post-Colonial Studies Series, 2015).
[17] Harro Maat and Sandip Hazareesingh (eds.), *Local Subversions of Colonial Cultures Commodities and Anti-Commodities in Global History* (Palgrave-Macmillan, Cambridge Imperial and Post-Colonial Studies Series, 2016).
[18] Alfredo Cesar Dachary and Stella Maris Arnaiz Burne, *El Caribe Mexicano: Una frontera olvidada* (Chetumal: Universidad de Quintana Roo, 1998).
[19] Arthur Demarest, *Ancient Maya: The Rise and Fall of a Rainforest Civilization* (Cambridge: Cambridge University Press, 2005); Anabel Ford and Ronald Nigh, *The Maya Forest Garden* (Walnut Creek: Left Coast Press, 2015). See as well the Mexican documentary *Maize in time of War* (2016).

[20] Hernan W. Konrad, 'Capitalism on the Tropical Forest Frontier: Quintana Roo, 1880s to 1930', in Jeffrey T. Brannon and Gilbert M. Joseph (eds.), *Land, Labor, and Capital in Modern Yucatan: Essays in Regional History and Political Economy* (Tuscaloosa: University Alabama Press, 1991): 143-171.
[21] Nelson A. Reed, *The Caste War of Yucatan* (Stanford: Stanford University Press, 2001); Terry Rugeley, *Rebellion Now and Forever: Mayas, Hispanics, and Caste War Violence in 1800-1880* (Stanford: Stanford University Press, 2009).
[22] Fernando Benítez, *Ki: el drama de un pueblo y de una planta*, (FCE, 1956); Alan Wells, *Yucatán's Gilded Age: Haciendas, Henequen, and International Harvester, 1860–1915* (Albuquerque: University of New Mexico Press, 1985); Sterling Evans, *Bound in Twine: The History and Ecology of the Henequen-Wheat Complex for Mexico and the American and Canadian Plains, 1880-1950* (College Station: Texas A&M University Press, 2007).
[23] María Cecilia Zuleta, *De Cultivos y Contribuciones. Agricultura y Hacienda Estatal en México en la "época de la properidad*". Morelos y Yucatán 1870-1910 (México, D.F.: Universidad Autónoma Metropolitana, 2006): 232.
[24] Howard F. Cline, 'El Episodio del Henequén en Yucatán', S*ecuencia* nº 8 (1987): 186-203.
[25] Alfonso Zamora Pérez, *Catalogo Crítico de las Máquinas desfibradoras México* (1830-1890) (México, D.F.: Universidad Autónoma Metropolitana, 1999); Rafael Barba, *El Henequén en Yucatán* (México, Secretaria de Fomento: 1895).
[26] Decreto de 13 de enero de 1857: 'Privilegio para José Esteban Solís por una Máquina de Raspar Henequén'.
[27] Eric N. Baklanoff and Jeffery T. Brannon: 'Forward and Backward Linkages in a Plantation Economy: Immigrant Entrepreneurship and Industrial Development in Yucatán, Mexico', *The Journal of Developing Areas*, Vol. 19, No. 1 (1984): 83-94.
[28] Archivo General de la Nación (AGN), Caja 12, Exp. 494 and Caja 12, Exp. 787.
[29] Rafael Barba: *El Henequén en Yucatán* (México, Secretaria de Fomento: 1895).
[30] Sterling Evans, 'King Henequen: Order, Progress, and Ecological Change in Yucatán, 1850–1950', in Robert Boyer (ed.), *A Land Between Waters: Environmental Histories of Modern Mexico* (Tucson: The University of Arizona Press, 2012):150-172.
[31],Alfonso Fabila, "Exploracion economico-social del estado de Yucatan", *El Trimestre Económico*, vol. 8, no. 31(3), (1941): 399.
[32] Allen Wells, 'From Hacienda to Plantation: the Transformation of Santo Domingo Xyucum', in Jeffrey T. Brannon and Gilbert M. Joseph (eds.), *Land, Labor, and Capital in Modern Yucatan: Essays in Regional History and Political Economy* (Tuscaloosa: University Alabama Press, 1991):112-142.
[33] Baklanoff 'Forward and Backward Linkages'.
[34] 'Hemp Twine: How and of What It Is Manufactured', *Boston Daily Globe* (28/08/1910).
[35] Victor M. Suarez Molina, *La evolución económica de Yucatán* (Mérida: Universidad de Yucatán, 1976):Vol. II., pp. 141-227.
[36] Plymouth Cordage Company, *The Plymouth Cordage Company: Proceedings At Its Seventy-fifth Anniversary,1824-1899* (Cambridge, Mass.: Printed at the University Press, 1900).
[37] Wells, 'From Hacienda to Plantation': 115.
[38] H. R. Carter, 'The Decortication of Fibrous Plants, with Special Reference to the Belgian Flax Industry', *Journal of the Textile Institute Proceedings and Abstracts*, 4:2 (1913): 231-265.
[39] Inés Ortiz Yam, *De Milperos a Henequeros en Yucatán, 1870-1937* (México DF: El Colegio de México, 2013): 140-1.
[40] Evans, *Bound in Twine*: 199-210.
[41] Antonio Rodríguez, *El Henequén: una planta calumniada* (México: CostaAmic, 1966): 339-42.
[42] Ibid.: 327-32 and 375-7.
[43] Peter Klepeis, 'Forest Extraction to Theme parks: the Modern History of Land Change', in B. L. Turner, Jaqueline Geoghegan and David R. Foster (eds.), *Integrated Land-Change Science and Tropical Deforestation in the Southern Yucatán: Final Frontiers* (Oxford: Oxford University Press, 2004): 39–62.
[44] Cyrus L. Lundell: 'Archeological Discoveries in the Maya Area', Proceeding of American Philosophical Society', Vol 72 (3), (1933), p. 147.
[45] On the history of chicle in the Yucatán peninsula and the chewing gum industry in the United States see Michael R. Redclift, *Chewing Gum: The Fortunes of Taste* (New York and London: Routledge, 2004); Jennifer P. Mathews, *Chicle*: *The Chewing Gum of the Americas, from the Ancient Maya to William Wrigley* (Tucson: University of Arizona Press, 2009).
[46] Luis G. Giménez, *El chicle: su explotación forestal e industrial* (México: Imprenta Manuel Casas, 1951).
[47] Redclift: *Frontiers*: 131-159.
[48] Ibid.
[49] Frank E. Egler, 'The Role of Botanical Research in the Chicle Industry.' *Economic Botany*, vol. 1, no. 2 (1947): 188–209.

[50] Frederic Dannerth: 'The Industrial Chemistry of Chicle and Chewing Gum'*, Ind. Eng. Chem.,* 9 (7), (1917): 679-682
[51] Egler 'The Role of Botanical Research'.
[52] Luis G. Gimenez, *El chicle*, p. 92-4.
[53] Claudio Vadillo, 'Una historia Regional en tres tiempos. Campeche s. XIII-XX', *Península*, Vol. 3, No. 2 (2008): 46-56; M. Ramos Díaz, 'La bonanza del chicle en la frontera caribe de México', *Revista Mexicana del Caribe* Año 4, nº 7: (1999): 172–93.
[54] Luis G. Giménez, *El chicle*, p. 95-7.
[55] Alan K. Craig, 'Logwood as a Factor in the Settlement of British Honduras', *Caribbean Studies*, vol. 9, no. 1, (1969): 53–62.
[56] Agustí Nieto-Galán, *Colouring Textiles: A History of Natural Dyestuffs in Industrial Europe* (Boston and London: Kluwer Academic Publishers, 2001): 16.
[57] Pascale Illegas and Rosa Torras, 'La extracción y exportación del palo de tinte a manos de colonos extranjeros: El caso de la B. Anizan y Cía', *Secuencia*, 90 (2014): 79-93.
[58] *The Chemical Trade Journal and Chemical Engineer*, Volume 57 (1915): 518;
[59] Claudio Vadillo, 'Extracción y comercialización de maderas y chicle en la región de Laguna de Términos, Campeche, siglo XIX', in Mario A. Trujillo and José Mario Bolio (eds.), *Formación empresarial, fomento industrial y compañías agrícolas en el México* (México DF: CIESAS): 299-318; Angel E. Cal ,'Capital-Labor Relations on a Colonial Frontier: Nineteenth-Century Northern Belize', in Jeffrey T. Brannon and Gilbert M. Joseph (eds.), *Land, Labor, and Capital in Modern Yucatan: Essays in Regional History and Political Economy* (Tuscaloosa: University Alabama Press*,* 1991): 83-107.
[60] H. J. Conn, 'The History of Staining Logwood Dyes', *Stain Technology* 4:2 (1929) , 37-48
[61] Víctor Sánchez Molina, *La evolución económica de Yucatán a través del S XIX* (Mérida: Universidad de Yucatán, 1977).
[62] Molina, *La evolución económica*: 214-6.
[63] Joris Mercelis, 'Corporate Secrecy and Intellectual Property in the Chemical Industry through a Transatlantic Lens, c.1860-1930,' *Entreprises et Histoire*, 2016/1: 32-46.
[64] Carsten Reinhardt and Anthony Travis, *Heinrich Caro and the Creation of Modern Chemical Industry* (Dordrecht: Kluwer, 2000): 57-59.
[65] Berthold Wuth, 'Substitutes for Indigo, Aniline Black, Logwood & c*.', Journal of the Society of Dyers and Colourists,* Volume 25, Issue 4 (1909).
[66] Michael A. Camille and Rafael Espejo Saavedra, 'Historical geography of the Belizean Logwood trade', *Yearbook - Conference of Latin Americanist Geographers*, Vol. 22 (1996): 77-85; Nieto-Galán: *Colouring Textiles*.
[67] Reinhardt: *Heinrich Caro.*
[68] Vadillo: 'Extracción y comercialización' de maderas': 299-318 and 307-11.
[69] Personal communication with Ian Inkster (4/9/2017).
[70] Redcliff: *Frontiers*: 136-144.