A Guilty Pleasure

How cocoa production is driving deforestation in the Ivory Coast

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Abstract

In 2019, four west African countries produced 74% of the world's total supply of cocoa (4,800,000tons)[1], and of that total Ivory Coast (Côte d'Ivoire) produced 62.5%. As the country's name suggests, elephants once abundantly roamed the rainforests of the Ivory Coast, but not any more. Many of the country's national parks and conservation lands have been cleared to make way for cocoa operations to feed demand from large chocolate companies. Food companies such as Nestlé are investing in cocoa farms and trying to identify new resources and efficient ways of producing their products since they have predicted that cocoa resources will be 'totally depleted' in the future.[2] Meanwhile the demand for cocoa beans, especially from the chocolate confectionery market, grows every year. This ballooning global demand for chocolate means that if no changes are made we won't have any chocolates available for Easter, Valentine's Day or Halloween, and higher cocoa cost will once again make chocolate a treat only the wealthiest can afford.

More significantly, *A Guilty Pleasure* aims to visualize how the monoculture cocoa industry is driving deforestation in the Ivory Coast. By drawing people's attention to this issue, my project reveals the bittersweet price we've paid for each pound of chocolate. Through bridges built between datasets, we can observe the cocoa industry's conflicting role in tropical deforestation and its impact on local suppliers more closely. As the name *A Guilty Pleasure* suggests, demand and supply of cocoa beans has a dual nature on a consumer level and through an economical perspective. Through zooming-in on cocoa production in the Ivory Coast as a case study, users will be able to connect the dots and form their own conclusions, about the need for a more sustainable model for the cocoa supply.

[1] "As Cocoa Harvest Begins, Risks Emerge From Major ...." 24 Oct. 2019, https://gro-intelligence.com/insights/articles/as-cocoa-harvest-begins-risks-emerge-from-major-producing-countries. Accessed 14 May. 2020.
[2] "Green supply chain - ScienceDirect." Accessed April 1, 2020. https://www.sciencedirect.com/science/article/pii/B9780128164495000023.

Introduction

"He showed the words 'chocolate cake' to a group of Americans and recorded their word associations. 'Guilt' was the top response."[3]

— Michael Pollan

In the past century, with the rise of developed machinery, the word "chocolate" has expanded to include a range of affordable treats for everyone. European and American countries are the main customers in the chocolate market: growing along with the household's average income level, the chocolate industry has been expanding steadily. In 2019, U.S. chocolate confectionery sales reached $25 billion, which is a 47.48% increase from 2009. Meanwhile rapid urbanization has created a growing middle class in the Asian continent, changing consumer tastes that has triggered an increasing appetite for chocolate. (India's demand for chocolate is booming as well – almost 230,000 tonnes were consumed in 2016, a 50% increase from 2011.)

The nutritional contents and ingredients of chocolate may vary by type. While many are interchangeable, there's one ingredient we can't make chocolate without: cocoa. Dark chocolate contains 30~90% cocoa content on average; milk chocolate contains less than 10%; white chocolate doesn't contain cocoa directly but cocoa butter is one of its main ingredients. On the other hand, the health benefits of consuming chocolate has never failed to be debated among nutritionists and in news articles. With the growing awareness of synthetic ingredients, most health-conscious consumers have turned their preferences towards premium organic chocolate or dark chocolate which is perceived as the healthier choice among all the types.

However, chocolate is "a guilty pleasure" not only because of its debatable effect on the human body, but also due to the "unnoticeable" aftereffects on the forest and its conflicting role on local economies. As the irreplaceable ingredient, cocoa has almost tripled its supply quantity in the past 38 years (from 1981 to 2019). In contrast to how much we love our chocolate, very few are aware of

[3] Pollan, Michael. *In Defense of Food: an Eaters Manifesto*. Turtleback Books, 2009.

where these cocoa beans came from and the environmental toll. How many forests are we sacrificing in order to make land for extra cocoa harvests?

The purpose of this project is to explore and visualize the actual bittersweet "prices" we've paid for each pound of chocolate. Stating clear about the challenges that cocoa cultivation is facing. Zooming in on Ivory Coast's economical status and geographical resources, where 60% of our cocoa beans came from. Discussing the cocoa plantation's conflicting role on local economy and environment. In 2019, Ivory Coast's growth stood at 7.5%, driven by higher cocoa revenues and greater social expenditures. Meanwhile, it has lost 2.78Mha of tree cover, equivalent to a 19% decrease in tree cover since 2000, and 730Mt of CO_2 emissions. Through analyzing the factors that may induce deforestation and each probability, we may see the correlation between cocoa farming and forest disappearance. Additionally, the study will also include what are some alternative decisions that can be made at each stage of cocoa plantation, for example the difference between monoculture and agroforestry, introduction of a possible quota or trading cap etc.

The implication of this project isn't opposed to the regular consumption of cocoa or trying to start an anti-chocolate movement. Humans have started to consume cocoa thousands of years ago therefore cocoa bean itself isn't evil, how we obtain it and consume it without limits, that's the guilty part. In fact this project emphasizes on addressing the importance and urgency of building a sustainable cocoa supply chain. Customers shouldn't be kept from unethical cocoa sources with its aftereffects attached, because in the end we are the one who is going to pay the "price". In order to explain these contents more thoroughly and instead of offering a subjective opinion, this visualization adopts a scrolly-telling structure, allowing users to dive into different datasets at their own paces. Target audiences are not limited to people who have a sweet tooth like me, but also hopefully would raise consciousness among a wider range of individuals.

Treatment

I. Cocoa Affection

Cocoa, which is also known as *cacao*, is a foundational brick of the chocolate empire. The cacao plant was first given its botanical name by Swedish natural scientist Carl Linnaeus, where he called it *Theobroma Cacao,* meaning *food of the gods* in Greek. Human usage of cocoa beans can be traced back to 4,000 years ago. Long before Richard Cadbury first put chocolates in a heart-shaped box for Valentine's day, it was an important part of Mayan wedding rituals. The bride and groom would exchange hot chocolate beverages during the ceremony, this tradition foreshadows chocolate's future status as a universal expression of love. From the provenance of cacao tree's given name to modern inventions of different chocolate confectionery, this *food of the gods* that many cultures ennobled as a curative drug, a culinary delight, and even a source of currency for commodity trading has retained its appeal over the centuries.

Throughout the 21st century, chocolate is mostly consumed for the purpose of pleasure and indulgence. "The silky-smooth texture that comes forth brings nothing but pure bliss. The perfect mix of bitter and sweet with a tinge of mint is pure luxury. Made with cakes and pastries, it adds an extra slice of heaven to every bite."[4] We've witnessed chocolate's acting role in numerous literature and movies, such as Forrest Gump, E.T. and Chocolat - eating chocolate remains a sensual and not cerebral experience. At the same time we've layered up cultural and emotional meanings on top of its silkiness. A survey conducted by the National Confectioners Association has found out that 80% of Americans prefer to share chocolate with their loved ones for Valentine's Day[5]. This may be due to the fact that chocolate contains a feel-good chemical called *anandamide*, taken from the Sanskrit word *ananda* which means joy, bliss, and delight. As one of its consequences, the demand curve of chocolate and cocoa beans peak every year around the same period of time.

[4] *"Chocolate | Quotes and descriptions to inspire creative writing." https://www.descriptionari.com/quotes/chocolate/. Accessed 22 Mar. 2020.*

[5] "Trade Regulations Database - NCA - National Confectioners." https://www.candyusa.com/trade-regulations-database/. Accessed 22 Mar. 2020.

However, among the diverse range of chocolate commercials nearly none of them have informed the coarse reality about where our chocolate comes from? Who is supplying the world with "inexhaustible" cocoa beans? Apparently cocoa beans weren't grown in the sweet Neverland but some places that are far far away from where they were consumed. This deliberate disconnection between raw materials and well-rounded products have successfully shifted customer's focus on the opportunity cost and environmental responsibility behind the consumption, but onto the purely indulgent sensation of savoring a piece of chocolate.

Meanwhile cocoa farmers are facing a series of challenges: the risk of diseases, inconsistent rains caused by global warming, labor shortage and buyers forcing them to sell at rock-bottom prices. What has even worsened the problem is that global demand for cocoa beans is increasing every year without any upper constraints. Back to 2001, world production of cocoa beans was 2,865,000 tonnes, led by four African countries Ivory Coast, Cameroon, Ghana and Nigeria with 72% of the total. Other major producers were Indonesia (19%) and Brazil (6.5%)[6]. With the growing middle class in asian continent, the cocoa market grows proportionally. 8 years later the quantity is almost doubled (4,824,000 tonnes) in which four west African countries occupy 76.4% of the supply market.

The obstacle on the way of expanding production is that cacao trees only grow in a limited geographical zone, between 10 degrees North and 10 degrees South of the Equator[7], therefore nearly 70% of the world crop today is grown in West Africa. Cocoa is a labour-intensive crop, its preparation involves eighteen steps and each one requires close and continuous attention. As pods do not ripen at the same time, the trees need to be monitored continuously. Any unexpected factors such as weather and pests would generate precarious outcomes to the cocoa farmers. While excess would crush the global price but deficiency would make their cocoa beans less competitive and then lead to profits' shrinkage even further. So far the supply is just enough to catch up with global demand, however try not to be deceived by the variety of chocolates sitting on the food shelf section

[6] "As Cocoa Harvest Begins, Risks Emerge From Major Producing Countries." Gro Intelligence. Accessed April 7, 2020. https://gro-intelligence.com/insights/articles/as-cocoa-harvest-begins-risks-emerge-from-major-producing-countries.
[7] "Cocoa Tree Seeds: Tips On Growing Cacao Trees." 4 Apr. 2018, https://www.gardeningknowhow.com/ornamental/trees/cocao-tree/growing-cacao-trees.htm. Accessed 23 Mar. 2020.

in most grocery markets, because without expansion on the land usage it's almost impossible to make more cocoa beans at this current rate. In order to frame the full issue of the "guilty pleasure", it's important to take into consideration both quantitative and qualitative data as well as those which were hidden from the public attention.

II. From Beans to Bars

"North of Ghana's cocoa-growing regions, the landscape changes from green to brown."[8] a phenomenon reported by Nellie Peyton from Thomson Reuters Foundation in one of his articles. The problems that will be unfolded in this project isn't as simple as a right or wrong question, similar to a bar of milk chocolate, it sits right at the brown boundary between "dark" and "white". Cocoa is one of the most popular cash crops—which are mainly grown for revenue—it certainly has irresistible attractions to the local farmers, but on the other hand it's driving deforestation at its farming location. Before we dive into the bitter aftermath caused by cocoa plantation, preface the beneficial sides first would prevent our understanding of the issue being one-sided.

"Five villages from both tribes are participating in the cacao project. Cacao trees are native in this area, but around 3,000 new seedlings have been planted to boost production, with 7,000 expected by the end of 2021."[9] On Jan 25th 2020, a journalist traveled to Brazil's largest indigenous reserve where violence is a recurrent problem around illegal gold mining camps, he witnessed how cocoa saplings have offered an alternative to illegal mining. From 2017 to last year, thousands of cacao trees were planted near Waikás and other villages in the remote Yanomami indigenous reserve; these cacao tree saplings were expected to boost the local economy though producing exclusive cocoa beans for the global premium chocolate market. President of the Wanasseduume association is hoping within five year these cocoa trees will replace illegal gold mining to become local people's

[8] "Aging cocoa trees provide opportunity for agricultural reform in ...." 30 Aug. 2018, https://www.csmonitor.com/World/Africa/2018/0830/Aging-cocoa-trees-provide-opportunity-for-agricultural-reform-in-Ghana. Accessed 22 Mar. 2020.
[9] "Cacao not gold: 'chocolate trees' offer future to Amazon tribes ...." 25 Jan. 2020, https://www.theguardian.com/environment/2020/jan/25/cacao-not-gold-chocolate-trees-offer-future-to-amazon-tribes-aoe. Accessed 22 Mar. 2020.

main income sources. At this particular location, cocoa plantation isn't just a new source of income, but also hatches the peace, stability and temporal hopes among the native tribes.

Nevertheless, similar stories are happening in other parts of the world where cocoa farming became natives' bread-and butter. Worldwide, 90% of cocoa is grown on small family farms of 2 to 5 hectares, while just 5% comes from large plantations of 40 hectares or more. Cocoa production provides livelihoods for between 40 and 50 million farmers, rural workers and their families in the Global South. In the Ivory Coast and Ghana, cacao accounts for 40% of their total exports and up to 90% of the farmers rely on cocoa for their primary income. [10] Therefore when we are discussing the impacts of cocoa production and the potential solution in response to minimize deforestation, it's not just to solve problems with a big number, we also need to address the qualitative data that's involved in the process which is someone's day to day livelihood, solutions for deforestation doesn't necessarily lie in the complete cut off cocoa plantation.

On the other side, the consequence of a nation or individual producer relaying on cash crops as its main economy sector may suffer low prices due to excess supply from elsewhere on the global market. In April 2017 Ivory Coast slashed the price of cocoa by 36%, these low prices are due to the global oversupply of the crop and cocoa bean's volatile pricing system. Evidently, the government was forced to drop the price and cut its annual budget by 10%. In May 2017 they announced a loss of $1.1 billion in export earnings. Pricing is an obvious threat to a farmer's livelihood but so are natural disasters and pests. In the early 1700s, a series of hurricanes wiped out much of Puerto Rico's cocoa trees , and since then the cocoa farming has never been recovered. Similarly at 1980s Witches' broom turned the beans to mush inside the pod, and wiped out huge harvests in Brazil which was the world's second largest producer at that point. That leads us to a more urgent question: how long will Ivory Coast still be able to supply the world with abundant cocoa beans? With the infusion of rising deforestation issues, where would the future of the cocoa market head towards?

[10] "Cocoa production in a nutshell | Make Chocolate Fair!." https://makechocolatefair.org/issues/cocoa-production-nutshell. Accessed 22 Mar. 2020.

Among numerous effects generated by cacao plantation, this project emphasizes primarily on the deforestation that has been triggered during and after the whole process, and in most circumstances these forests aren't revertable. In order to inform what ties the link between cacao trees and deforestation, more detailed analysis of cacao trees' common cultivation methods and the specific journey from raw cocoa beans to edible chocolate is required.

First and foremost, it's important to know that each ecosystem and its underlying functions depend heavily on both its current ecological attributes and historical legacies which means disturbances, natural or anthropogenic, can lead to long-term fluctuations in ecosystem structure. This would eventually lead to land-use change. But in general, the impact of human interference, for example in the form of agricultural activities, is larger than that of natural events. Agricultural systems can be established from contrasting ecosystems. The conversion of a tropical forest into an agricultural suitable environment is mainly achieved by slash-and-burn techniques, which are very similar all over the world.[11] All organic components whether it's above or below ground, seem to be highly influenced by past land-use which means not only the soil itself but also the organisms around it have living 'memories'.

A healthy cacao tree can produce approximately 30~40 cocoa pods a year on average, and inside each pod typically there are 20~50 cocoa beans. After removal of unhealthy looking beans, those left will go through 7 processing stages: fermentation, drying, roasting, winnowing, grinding, conching and tempering. After the final stage, cocoa beans are now successfully transformed into a finished product with a sophisticated taste. It's inevitable that there will be some losses at each stage so roughly 1 pound of chocolate needs 500 cocoa beans as raw materials at the beginning. In a nutshell a whole year's yield from one tree can make 2 pounds of chocolate. In 2017, Switzerland's chocolate consumption per capita was 8.8 kilograms (19.36 pounds)[12] which requires 9 cacao trees' annual production. Presumably not every cacao tree's yield is the same as well as each pod's size is different among species and geographic location, but this will give us an idea that the equation between cocoa

[11] "Long-term dynamics of cocoa agroforestry systems ...." 1 Apr. 2019, https://www.sciencedirect.com/science/article/pii/S0167880919300283. Accessed 31 Mar. 2020.
[12] "Global chocolate consumption per capita in 2017, by ... - Statista." 28 Jan. 2020, https://www.statista.com/statistics/819288/worldwide-chocolate-consumption-by-country/. Accessed 24 Mar. 2020.

beans and chocolate isn't one to one. The formula here isn't aimed for absolute precision because the previous calculation model is based on the prerequisite of nice weathers with no natural or human catastrophe intervened which means if there are any other additional factors happened, each pound of chocolate will cost more tree's production.

In the light of knowing each cocoa tree has limited yield quantity and its produce rate declines as growing old, most cocoa farmers chose to adopt new crops while previous production centers collapsed. There are two types of deforestation that can be triggered by cocoa plantation. The first type took place at the beginning of each cultivation process. Most cocoa is grown in monocultures with little or no shade which is known as the full-sun system, requiring the removal of all surrounding trees either at the beginning or gradually during the growing phrase. "The land needs to be cleared and prepared before planting cocoa seedlings and then cocoa trees take 3-5 years to yield a crop." A report from the International Cocoa Organization has made clear about cocoa plantation. People may wonder why can't we plant cacao trees on previously used crop or fallow land? That's because planting a crop after clearing primary forest can have strong economic advantages, oftenly has been interpreted as 'forest rents'. Biggest differences between forests and replanted sites are soil fertility, microclimatic conditions and biological factors such as pest and disease pressures. All these factors are crucially important in terms of determining production costs, yields, and risks of tree mortality when a new crop is planted. Cacao trees will benefit from low weed pressure, high soil fertility, and a microclimate that is conducive to the development of these drought-sensitive understory trees if they were planted in virgin forest soil.[13] This helps to explain why in most tropical regions cocoa sites have a strong tendency to follow the trace of vanishing forests, and many protected areas being "completely converted to farms". Continuous increase in world production of cocoa beans over the last century has brought the conversion rate of natural habitats into agricultural land onto the rise too. A cycle of "boom-and bust"[14], combined with the transformation of the principal cocoa growing regions to move from place to place has consumed

[13] "Chocolate forests and monocultures - ResearchGate." https://www.researchgate.net/publication/261713726_Chocolate_forests_and_monocultures_-_an_historical_review_of_cocoa_growing_and_its_conflicting_role_in_tropical_deforestation_and_forest_conservation. Accessed 24 Mar. 2020.
[14] "Chocolate forests and monocultures - ResearchGate." https://www.researchgate.net/publication/261713726_Chocolate_forests_and_monocultures_-_an_historical_review_of_cocoa_growing_and_its_conflicting_role_in_tropical_deforestation_and_forest_conservation. Accessed 23 Mar. 2020.

forests faster than ever. When cycles started they led to the opening up of new forests, sometimes at a tremendous speed. Where they ended they left behind, in best cases, disease-infested and low productivity land which will be hard to rehabilitate. But in most cases, the outcome is the degraded soil which has already lost its nutrients and dried up.

Targeting the first type of deforestation, the UN Food and Agriculture Organisation advocated a better alternative to monoculture farming method which is agroforestry.[15] In the short term, monocultures have been found to produce up to 40% higher yields compared with agroforestry due to its high efficient 'slash-and-burn' technique. But agroforestry has demonstrated that it can benefit the environment as well as provide multiple economic and social benefits. Agroforestry will make cacao trees less vulnerable to the impacts of climate change as well. But there are no regulations on cocoa farming at this moment, it is very up to chocolate brands' very own decisions to choose between which they value the most: long-term sustainability or short-term profits. Many environmentally-conscious chocolate makers already source their beans from farms or cooperatives that utilise cacao agroforests, but still other chocolate giants haven't made their sources of cocoa transparent to all customers.

Secondary deforestation is triggered during the process. Because Cacao trees can be easily impacted by climate, any unexpected rising temperature or drought seasons could reduce soil's fertility. A common method adopted by most farmers is that they would either leave some tall trees within the cocoa plantation site or plant some banana taro trees before the cacao so the taller trees will give shades for the young cacao sapling. When the cocoa trees have grown taller, they need less shade. Farmers would prune the big trees and cut off those branches that cast too much shade. When the plantation is well cared for, they can cut down all the big trees.

[15] "What is Cacao Agroforestry? | Cacao Magazine." 14 Jan. 2020, https://readcacao.com/blog/what-is-cacao-agroforestry/. Accessed 24 Mar. 2020.

III. As Cocoa Grows

Cocoa farming is a major contributor to the economies of several West African countries. The last piece of chocolate you ate likely had its roots in West Africa, where two-thirds of cocoa beans are produced, most likely it's grown up in Ivory Coast (Côte d'Ivoire) where cocoa sales accounting for approximately 10% of the country's GNP. Ivory Coast has Africa's fastest growing economy according to the IMF[16], due to things like political stability, a growing middle class, and especially exports for cash crops such as cocoa.

Deforestation is a global scope problem and can be caused by many factors but in order to avoid generalizing the issue, this section will zoom into the largest supply country of cocoa beans currently: Ivory Coast. Using datasets to show how cocoa has reformed this land at the expense of the forests. In the past half-century, the world is losing trees faster than ever, the latest report shows that deforestation increased nearly 30 percent between 2018 and 2019. It marks the highest rate of deforestation since 2008 and amounts to a cleared area larger than Yellowstone National Park. Most importantly the deforestation was shifted from Brazil and Indonesia to a wider range of countries. "In 2002, just two countries—Brazil and Indonesia—made up 71 percent of tropical primary forest loss. More recent data shows that the frontiers of primary forest loss are starting to shift. Brazil and Indonesia only accounted for 46 percent of primary rainforest loss in 2018"[17]

Ivory Coast is one of the countries which have lost its rainforests at a astonishing rate, more than 19 percent of its tree cover were wiped out during 7 years time period[18], most following an illegal invasion by as many as a million landless people into national parks and other supposedly protected forests. The Marahoue National Park alone has 30,000 illegal inhabitants. The invaders are growing cocoa to supply the global chocolate business.

A century ago, the introduction of cocoa farming brought many economic opportunities to this land, also marking the beginning of deforestation. Ivory coast is gifted with an advantageous

[16] "Côte d'Ivoire and the IMF - International Monetary Fund." https://www.imf.org/en/Countries/CIV. Accessed 26 Mar. 2020.
[17] "Here's what deforestation looks like in 2019 ...." http://www.mightyearth.org/heres-what-deforestation-looks-like-in-2019-and-what-we-can-do-about-it/. Accessed 25 Mar. 2020.
[18] "Global Forest Watch." https://www.globalforestwatch.org/. Accessed 25 Mar. 2020.

location in the forest belt where the savanna reaches down to the sea and the seasonal dryness of the climate precludes the planting of drought-sensitive crops like cocoa. It has the highest level of biodiversity in West Africa. As of 2016, 252 species of mammal, 666 species of bird, 153 species of reptile, 80 species of amphibian, 671 species of fish and 3660 species of vascular plant had been recorded in Ivory Coast.[19] While the majority of Ivory Coast's forests exist as small, fragmented forest islands, most of these areas are designated as national parks and protected forest reserves.

A research paper published by the Anthropology Department at The Ohio State University has revealed that there is a significant positive correlation between cocoa farming and the absence of primate species inside Ivory Coast's national parks and reserves.[20] One of the explanations for the biodiversity reduction is the disappearance of forests caused by cocoa farming.

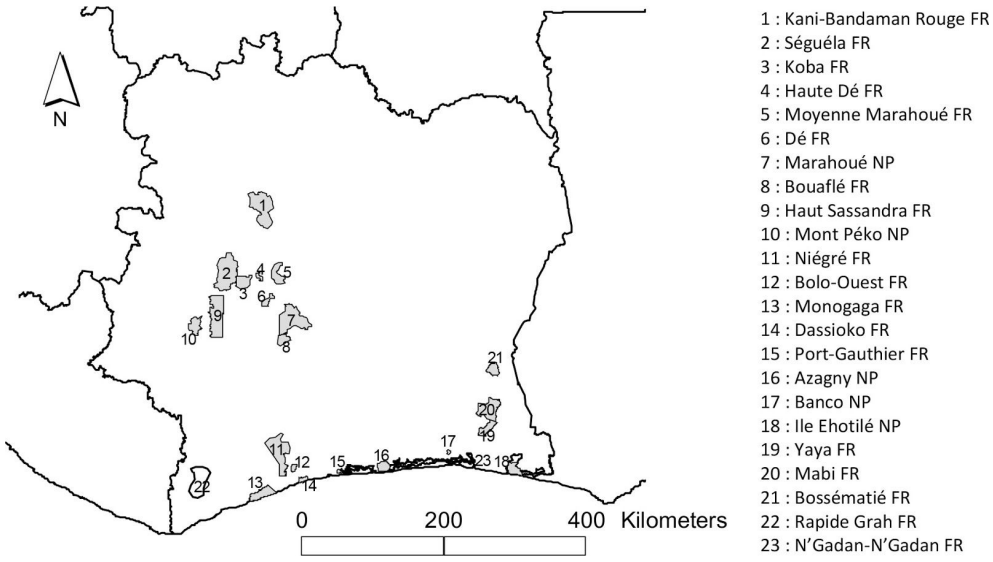


fig 1

The graph above, created by E.Anderson Bitty, Sery Gonedele Bi, Jean-Claude Koffi Bene and cited in the research paper first published March 1, 2015 to shows the location of 23 protected areas surveyed in their research

Of the 23 forest reserves (fig1) they visited, 16 of them have exceeded 65% degradation quotients (fig2). 93% of illegally grown agricultural products in these surveyed national parks is cocoa. Other

[19] "Côte d'Ivoire - The Rainforest - Mongabay." https://rainforests.mongabay.com/20cotedivoire.htm. Accessed 26 Mar. 2020.
[20] "Cocoa Farming and Primate Extirpation Inside Cote D'ivoire's ...." 1 Mar. 2015, https://journals.sagepub.com/doi/full/10.1177/194008291500800110. Accessed 26 Mar. 2020.

crops encountered are subsistence crops such as bananas, yams, maize, rice, and miscellaneous vegetables interspersed and associated with young cocoa trees. Of the approximately 4,392 km^2 surveyed, 3,239 km^2 have already been transformed into cocoa plantations. Based on the mean annual yield of cocoa in Ivory Coast, the estimated annual yield of cocoa from farms within these protected areas is 195,600 tons. Therefore it's a significant and positive correlation between deforestation and cocoa plantations. During their field trip they also discovered that in some areas cocoa farmers plant the young cocoa sapling among other protected tree kinds, then at the bird's eye view level because these trees still live within the preserved area, they won't be accounted as part of the deforestation number. And from the satellite image, 'forest' cover still looks the same as before.

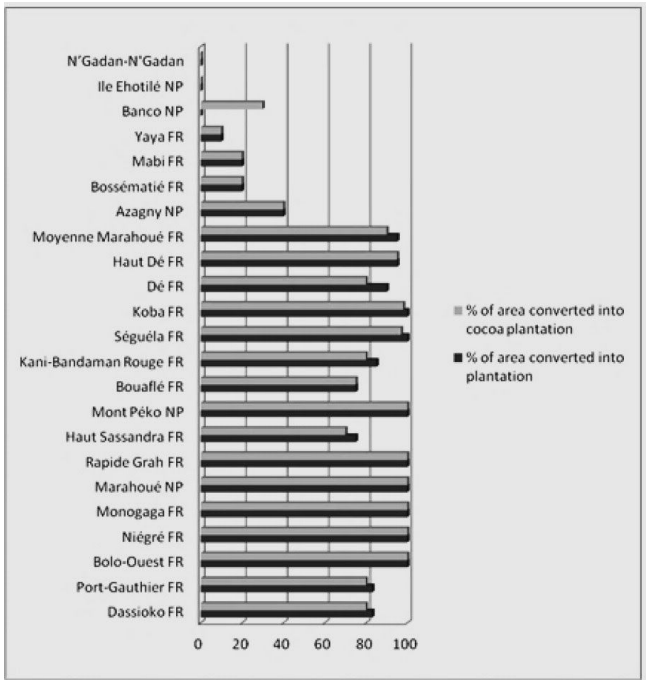


fig 2

The graph above, created by E.Anderson Bitty, Sery Gonedele Bi, Jean-Claude Koffi Bene and cited in the research paper first published March 1, 2015 to show Cocoa Farming and Primate Extirpation Inside Cote D'ivoire's Protected Areas

Similar finding on potential measuring error has been addressed in another study, "Temporary losses from shifting cultivation make up 93 percent of forest cover loss in Africa. Nonetheless, the analysis fails to distinguish between different types of tree cover. So when logged natural forests are replaced by commercial plantations, the change is simply recorded as regrowth, even though most

of the former biodiversity may be lost."[21] The importance of acknowledging this issue in terms of calculating forests' data is that there might exist a margin of error when people try to measure the forest cover loss, as it's mentioned in the earlier report the number highly depends on whether researchers recognize commercial plantations as part of tree cover or not.

Additionally, a study focusing on what factors have caused deforestation in one of the classified forests *Haut-Sassandra*.[22] has pointed out that there are twelve kinds of disruption that might cause deforestation. The most frequent disruptions are cacao plantations, with a frequency rate of 23.32%. These plantations are between a few months and under ten years old. Fallen trees after slash-and-burn and trees burnt at the base of the trunk occur with a frequency rate of respectively 21.06% and 18.84% of the overall disruptions of the environment. Uprooted trees are not frequent in the classified forest, they account for 4.79% of disruptions. They are essentially due to the wind or other natural causes. To sum it up, the most frequent types of disruption are cacao plantations, around 95% of the disruptions recorded are of anthropic origin and 5% of natural origin.

IV. Behind the Barcodes

Miles away from most cocoa beans' hometown, after they 'graduated' from the factory as a member of the chocolate family. They are heading towards different markets, from street-corner bodegas to high-end department stores where they became accessible to all customers.

In 2019, total net sales of the leading confectionery companies worldwide was 83,977 million dollars, that's almost equal to the value of total processed petroleum oils which have been exported from the US in the same year (87,508 million dollars).[23] Among them Mars Inc, Ferrero Group and Mondelez International share half of the total revenue, and it's declared on their websites that their

[21] "Conflicting Data: How Fast Is the World Losing its ... - Yale E360." 9 Oct. 2018, https://e360.yale.edu/features/conflicting-data-how-fast-is-the-worlds-losing-its-forests. Accessed 25 Mar. 2020.
[22] "Ivory Coast - ScienceDirect.com." https://www.sciencedirect.com/science/article/pii/S2351989416300774. Accessed 26 Mar. 2020.
[23] "United States Top 10 Exports - World's Top Exports." 5 Mar. 2020, http://www.worldstopexports.com/united-states-top-10-exports/. Accessed 7 Apr. 2020.

main cocoa sources are from Ivory Coast and Ghana[24]. However, it would be too subjective to say customer's consumption lies at the root of the illegal cocoa farming inside Ivory Coast's protected forests. Because during the whole process, starting from the moment when the seeds were planted into the soil to the last mouthful bite of a piece of chocolate, there were lots of alternative decisions that could be made at each link to prevent deforestation getting worse. Therefore we all contributed to the problem and we shouldn't just blame one or another for the responsibilities and to ignore the facts about what we can do.

First and foremost, it would be wise to put aside our altercation and stop treating it like somebody else's problem. If you are a chocolate lover, then an unsustainable cocoa supply chain would trigger the cocoa bean's price to inflate which would eventually raise the price for each chocolate bar. And in fact, this has already taken the unnoticeable form of 'shrinkflation'—the process of items shrinking in size or quantity while their prices remain the same or increase—in 2009 Mars reduced the size of their Mars bar from 62.5 grams to 58 grams, while the price remained at 37 pence. Seven years later Mondelez International again reduced the size of the UK 170g Toblerone bar to 150g, while the 400g bar was reduced to 360g. This was secretly done by enlarging the gap between the chocolate triangles.[25] On the other hand, if you've never been a huge fan of chocolate, the deforestation problem still would affect you through the impacts of climate change. In regards to the increasing awareness of significant environmental degradation caused by human activities led to climatic changes, the EU(European Union) has announced that "a first draft of the EU legal framework report will be published in May, due diligence regulation for the cocoa sector could be in place within two years."[26] This and all other regulations which were posed to companies by governments all aim at zero environmental and human rights violations in the cocoa supply chain.

Therefore the least effort we can contribute is to not waste any chocolate (this is applicable to other food too). If we search "chocolate bath challenge" on youtube, more than 100 videos would show up

[24] "Managing Our Land for Generations to Come | Mars, Inc.." https://www.mars.com/sustainability-plan/healthy-planet/managing-land-use. Accessed 7 Apr. 2020.
[25] "Toblerone triangle change upsets fans - BBC News." 8 Nov. 2016, https://www.bbc.com/news/uk-37904703. Accessed 7 Apr. 2020.
[26] "EU due diligence laws for cocoa sector could be in force by ...." 11 Mar. 2020, https://www.confectionerynews.com/Article/2020/03/11/EU-due-diligence-laws-for-cocoa-sector-could-be-in-force-by-2022. Accessed 7 Apr. 2020.

and the lastest was uploaded two weeks ago. I'm not opposed to the mukbang videos or any people who can eat more than normal consumption, as long as when you eat the food, you are appreciating it as much as the air you are breathing in. That's the minimal respect we could show to nature, farmers, factories who make this crumb of food possible.

Further contributions could be made possible through paying attention to where each chocolate company's cocoa resources are coming from? Are they mixed in with 'dirty' cocoa? Are their cocoa sources traceable on the website? There are companies which have already taken actions to slow down the wheel of deforestation, it's never too late for us to recognize and support their efforts. However companies' dedications are distributed at different levels. Since the start of this century, there is a growing pressure on chocolate companies to eradicate child labour. In regards to that, chocolate companies have long associated themselves with charitable initiatives. Same amount of attention was paid to water usage, locals' life improvements and environmental protections.

It's ubiquitous to see a link on almost every chocolate company's homepage says "sustainable development", after you click on it most likely you will open up a webpage that is composed of smiling face images and optimistic subheadings. This gesture did showcase they are aware about current issues, yet lack of details can't necessarily prove the effectiveness of their initiatives. And in fact so far these approaches have not proved very effective. "we all have unfortunately not got the traction that we need to really eliminate child labour," says Benjamin Smith, a technical specialist on child labour at the International Labour Organization in Geneva. Part of the problem, Mr Smith says was due to the certification process was hard to monitor and subject to manipulation. "A lot of energy and resources went into certification, which could have been more profitably invested in the root causes."

Same with the stop deforestation proposal, unless we see the detailed documented plans, there is no guarantee that actual actions were taken in place to achieve the goal. Ferrero Group released its action plan to fulfill its commitment to the Cocoa and Forest Initiative signed between leading cocoa and chocolate companies and the governments of Côte d'Ivoire and Ghana in 2017. The

collective aim is to end deforestation, restore forest areas, and create better lives for farmers and their communities in these cocoa producing countries. This report documented all the commitment actions and what's the expected goal by 2022.[27] This year Nestle also released a report in which you can trace their mapped farmers in Ivory Coast as well as some key activities they will undertake to end deforestation.[28] The initiative isn't limited to the report format, Mondelez International has created an interactive map to visualize individual farmers and their communities that are participating in Cocoa Life.[29] This doesn't suggest their contribution in stopping deforestation, but making the supply sources transparent to consumers can also eliminate the possibility of using cocoa beans from illegal farming.

In another direction, according to a Cocoa & Forests Initiative (CFI) co-created by Mondelez International with governments has mentioned that a key driver of deforestation is poverty.[30] Because cocoa is grown almost entirely by smallholder farmers, if a farmer wanted to earn more, he or she had to produce more, which would mean using more land. However, since the Ivory Coast is running out of farmland, it has to fight to increase farmers' earnings so they are not tempted to illegally grow cocoa in protected forests. Consequently they are helping to make farms more productive with yield-improving agricultural practices, such as planting shade trees around the cocoa-growing trees to create better growing conditions for cocoa. They also encourage farmers to diversify their income by investing in other areas, this progress makes farming more attractive and farmers less likely to cut down trees to plant crops elsewhere. Therefore, there are different approaches that can supervise or eliminate deforestation at Ivory Coast. As part of the study, I organized a table which summarizes some company's commitment towards deforestation which you can view in detail at the data and methodology section.

More or less, the awakening awareness about a sustainable cocoa supply chain's importance has brought inspiration to some proposals and initiatives among chocolate companies. Until the day when we see the actual drop in deforestation data, we can't conclude whether they are effective or

[27] "DETAILED ACTION PLAN COTE Dâ•ŽIVOIRE.xlsx - Amazon S3." https://s3-eu-west-1.amazonaws.com/ferrero-static-qa/globalcms/documenti/2605.pdf. Accessed 9 Apr. 2020.
[28] "CFI report - Nestle." https://www.nestle.com/sites/default/files/2020-03/nestle-cfi-progress-report.pdf. Accessed 9 Apr. 2020.
[29] "Interactive Farm Map - Cocoa Life." https://www.cocoalife.org/in-the-cocoa-origins/interactive-map. Accessed 9 Apr. 2020.
[30] "Interactive Farm Map - Cocoa Life." https://www.cocoalife.org/in-the-cocoa-origins/interactive-map. Accessed 9 Apr. 2020.

not. Meanwhile we can show that we care about the actual 'cost' that we are paying for each chocolate bar by purchasing chocolate which has a clear label of where the cocoa beans were coming from.

Data and Methodology

I. Data Sources

The fundamental purpose of this study is to identify how the cocoa industry is driving deforestation in Ivory Coast, through understanding what triggered the issue, we would remedy the problem with potential solutions.

This project isn't based on a singular data source and requires aggregation of multiple available datasets together in order to offer the breadth and depth analysis on this topic. In section 3 *As Cocoa Grow* I also included the evidence and research from previous studies about Ivory Coast's ecosystem and forests which can support the strong correlation between cocoa plantation and deforestation.

Datasets used in this project were mostly collected from governmental or non-profit organizations dedicated to environment study or forests' monitoring. Some datasets were collected from cocoa focused organizations such as ICCO (International Cocoa Organization)[31], World Cocoa Foundation[32] and ICI (International Cocoa Initiative)[33]. When I use the datasets from these specialized organizations, I would compare them with other sources too, not because of questioning authority or credibility, but to confirm the definition of certain terms align with general cognition through weighing out the data points. For example, in the dataset about global cocoa production in 2019, does the *cocoa* here refer to raw beans or finished products (in powder format)? After comparing across all other datasets, if the numbers fall into a certain range then I would be able to

[31] "The International Cocoa Organization." https://www.icco.org/. Accessed 4 Apr. 2020.
[32] "World Cocoa Foundation." https://www.worldcocoafoundation.org/. Accessed 4 Apr. 2020.
[33] "About Us - ICI Cocoa Initiative - International Cocoa Initiative." https://cocoainitiative.org/about-ici/about-us/. Accessed 4 Apr. 2020.

confirm it's the right one, if numbers conflict or dramatically different then I would go back to each dataset's methodology behind to see which one is more reliable.

II. Data Limitations

Difficulties of collecting cocoa and forest's data lie in two aspects. First and foremost because of the sensitivity of the subject and technical limitations it's impossible to acquire first-hand data without relying on a third platform or application. This means I can't calculate global cocoa production or the forest loss data but to either use the data that's already been obtained by other organizations (eg. consumption/production data) or through the tool they've developed (eg. global forest watch). But even the datasets gathered by different research groups in the past are still possible to obtain the margin of error based on their chosen methodology. For example, there are two main data sources for tree loss, and they are increasingly contradictory, a dataset collected from Global Forest Watch is compiled from satellite images by the World Resources Institute and on-the-ground observations. Based on the data, tree cover declined in 2017 for 72.6 million acres, 50 percent more than in 2015. However, the deforestation data from the Global Forest Resources Assessment which is compiled from government inventories by the Rome-based UN Food and Agriculture Organization, advocates that the deforestation rates have actually declined in the past decade.

Both datasets are stating the truth, the drastic difference is due to their different methodologies about comparing "loss" and "gain". In Global Forest Watch's measurement, "tree cover" does not equate to "forest cover." Therefore they don't take commercial plantations as part of the forests' regrowth, because the soil and ecosystem structure have been changed and they are non-restorable, while GFRA estimates the annual net loss, once forest regrowth and commercial plantations are taken into account, the change is barely. In regards to the soil's fertility left behind after cocoa plantation is completely different than unspoiled, the definition of forest cover in this project aligns with Global Forest Watch which only includes natural untouched forests.

Secondly, it's hard to measure cocoa consumption data compared to its production. Because production data is mainly based on the country's exports value so researchers would be able to estimate the total annual yield quantity. Cocoa can be consumed in various ways, the chocolate industry occupies the largest share but that doesn't necessarily mean if we measure how much chocolate has been consumed annually we would get the total quantity of how much cocoa has been consumed worldwide. However during my research I found out that before we consume cocoa beans, there is one unavoidable link during the manufacturing process: grinding. Therefore total cocoa beans' usage can be expressed through the grinding quantity which is more accurate than chocolate consumption solely.

Third challenge is due to the fact that all datasets were collected from various sources, each of them came with a different measure unit attached. It's part of my data cleaning and reorganizing task to unify those units across all datasets before importing them into my visualization project. With compatible units audiences will access the information more easily and this will reduce the confusion as well.

Following tables includes all the direct links to the data sources that's been used in this project, I grouped them by section so you can browse them more easily:

Section 1 Cocoa Affection

Data	Description	Access
Global Cocoa Production in 2019	**Gro Intelligence** "As Cocoa Harvest Begins, Risks Emerge From Major ...." 24 Oct. 2019	https://gro-intelligence.com/insights/articles/as-cocoa-harvest-begins-risks-emerge-from-major-producing-countries
Global Cocoa Trade	**Gro Intelligence** "Developing Economies Challenge Europe's Chocolate Reign ...." 16 May. 2018	https://gro-intelligence.com/insights/articles/developing-economies-challenge-europe-chocolate
Global Cocoa Trade Data	**Resource Trade.Earth** The trade data on this site are from the Chatham House Resource Trade Database (CHRTD)	https://resourcetrade.earth/data?year=2017&exporter=384&importer=eax&category=896&units=value
World cocoa bean production, grindings and stocks	**International Cocoa Organization**	https://www.icco.org/about-us/icco-news/408-may-2019-quarterly-bulletin-of

		-cocoa-statistics.html

Section 2 From Beans to Bar

Data	Description	Access
Cocoa, better farming series	**Food and Agriculture Organization of the United Nations**	http://www.fao.org/3/ad220e/AD220E03.htm#ch3.2
Information Sheet on Cocoa	**Food and Agriculture Organization of the United Nations**	http://www.fao.org/docs/eims/upload/216251/Infosheet_Cocoa.pdf
Cacao Agroforestry	**Cacao Magazine**	https://readcacao.com/blog/what-is-cacao-agroforestry/
Chocolate: The Journey from Beans from Bars	**Rainforest-alliance.org**	https://www.rainforest-alliance.org/
From Cacao Bean to Chocolate Bar	**Cargill**	https://www.cargill.com/food-beverage/na/from-bean-to-bar
Business processes and information systems in the Ghana cocoa supply chain: A survey study	**NJAS - Wageningen Journal of Life Sciences** Volume 92, December 2020, 100323	https://www.sciencedirect.com/science/article/pii/S1573521419300740
Long-term dynamics of cocoa agroforestry systems established on lands previously occupied by savannah or forests	**Agriculture, Ecosystems & Environment** Volume 275, 1 April 2019, Pages 100-111	https://www.sciencedirect.com/science/article/pii/S0167880919300283
The production process – from cocoa beans to semi finished products	**European Cocoa Association**	https://www.eurococoa.com/en/cocoa-story/cocoa-story-the-production-process-from-cocoa-beans-to-semi-finished-products/

Section 3 As Cocoa Grow

Data	Description	Access
Cote d'Ivoire: Sustaining Its Economic Transformation	**International Monetary Fund**	https://www.imf.org/en/News/Articles/2018/06/29/NA-062918-Cote-d-Ivoire-Sustaining-Its-Economic-Transformation
Cocoa farmers in west Africa at mercy of global markets	**Financial Times,** Opinion Agricultural production	https://www.ft.com/content/75d656c0-be84-11e9-9381-78bab8a70848
Major Natural Resources Of The Ivory Coast	**WorldAtlas**	https://www.worldatlas.com/articles/what-are-the-major-natural-resources-of-the-ivory-coast.html

Cocoa crops are destroying the forest reserves of the classified forest of Haut-Sassandra (Ivory Coast)	**Global Ecology and Conservation** Volume 8, October 2016, Pages 85-98	https://www.sciencedirect.com/science/article/pii/S2351989416300774
Cocoa Farming and Primate Extirpation Inside Cote D'ivoire's Protected Areas	**Tropical Conservation Science**	https://journals.sagepub.com/doi/full/10.1177/194008291500800110
Conflicting Data: How Fast Is the World Losing its Forests?	**Yale Environment 360,** Published at the Yale School of Forestry & Environmental Studies	https://e360.yale.edu/features/conflicting-data-how-fast-is-the-worlds-losing-its-forests
The Real Price of a Chocolate Bar: West Africa's Rainforests	**Yale Environment 360,** Published at the Yale School of Forestry & Environmental Studies	https://e360.yale.edu/features/the-real-price-of-a-chocolate-bar-west-africas-rainforests
Vulnerability to climate change of cocoa in West Africa: Patterns, opportunities and limits to adaptation	**Science of The Total Environment** Volume 556, 15 June 2016, Pages 231-241	https://www.sciencedirect.com/science/article/pii/S0048969716304508
Cocoa Farming and Primate Extirpation Inside Cote D'ivoire's Protected Areas	**SAGE Journals,** Volume: 8 issue: 1, page(s): 95-113	https://journals.sagepub.com/doi/full/10.1177/194008291500800110

Section 4 Behind the Barcode

Green Supply Chain	**The Interaction of Food Industry and Environment** **2021,** Pages 35-61	https://www.sciencedirect.com/science/article/pii/B9780128164495000023

Following tables showcases each company's commitment towards deforestation and sustainable cocoa plantation. *("Y" stands for "Yes", "N" stands for "No". Data is up to date until May 18th.)*

Company	Improving West African Cocoa	Agroforestry	Deforestation Free	Reduce Water Usage	Traceability	Living Income	Evidence / Report
Mars Inc.	Y	Maybe(the link is broken)	Maybe(the link is broken)	Y	Y	Y	https://www.mars.com/about/policies-and-practices/land-use
Ferrero Group	Y	Y	Y	Y	Y	Y	https://s3-eu-west-1.amazonaws.com/ferrero-static/globalcms/documenti/3788.pdf
Mondelez International	Y	N	Y	N	Y	Y	https://www.cocoalife.org/
Meiji Co.	N	N	N	Y	N	N	https://www.

							meiji.com/global/sustainability/caring_for_the_earth/
Hershey Co.	Y	N	Y	Y	Y	Y	https://www.thehersheycompany.com/en_us/sustainability/shared-business/responsible-sourcing.html
Nestle SA	Y	Y	Y	Y	Y	Y	https://www.nestle.com/sites/default/files/2020-03/nestle-cfi-progress-report.pdf
Lindt & Sprungli AG	Y	N	N	Y	Y	Y	https://www.lindtusa.com/sustainability-our-commitment-
Pladis	Maybe (not many details mentioned)	N	N	N	N	Y	https://www.pladisglobal.com/our-promise/responsible-supply-chain/
Godiva	Y	N	Y	Y	N	Y	https://production-direct-godiva.demandware.net/on/demandware.static/-/Sites-Godiva-Library/default/v1ac4208182b935e5b251fb0f44bb1a7f93979270/Godiva%20Cares/Godiva_CFI%20-%20CDI%20-%2019.pdf?version=1,582,920,377,000

III. Storytelling Narrative Structure

Inspired by the explanatory genre of a storytelling data visualization's structure, this project adopts the scrolly-telling method which allows audiences to dive into the data stories at their own paces. A scrolled based transition will guide them through sections while visualization automatically synchronizes with descriptive contexts. My target audiences are lay people who aren't professionals or experts in both the cocoa and chocolate industry, therefore in order to avoid faultage of conception, I included definitions for some terminology words that appeared in the visualization.

Considered the vast scope of datasets and how verbose the webpage length could become. Instead of arranging all contents on the same page and involving an "endless" scrolling, I decided to divide them into four sections based on the internal dependency. Meanwhile the section sequence is tailored based on narrative logics which will make the datasets and statements suggested in this project more pellucid to my target audiences.

IV. Design Decisions

This thesis project went through a long process from ideation, mind-map, prototyping, data cleaning to final execution. I'm using d3.js as the main language in this project, in some sections I also utilized Mapbox GL to present the spatialized data. Following paragraphs will explain some of my design decisions with details.

Users land on a homepage which adopts a horizontal scrolling structure. The "chocolate label" on the homepage summarizes my project title and provides a glance at the topic but not giving away too much information at the same time. As they scroll to the right side, it feels like unwrapping a chocolate bar and it also reveals the introduction about this project as well as a menu of each section's title. Although users may choose any section to begin with, the suggested order is from PART1 to PART4. Within each section they can always navigate forward or backward.

Each section curates different contents but also belongs to the same family, in order to balance the consistency and variation, I came up with a visual style guide for this project. There are two typefaces used in the design, *Gopher* as the display font for all the titles and subtitles while *Courier* as the main font for all the body texts and legends. On the opening slide located at the beginning of each section, there is a small svg shape which foreshadows the following contents and also serves as an introduction to the measurement unit which will be utilized in this section. Chart selections are highly decided upon data types, for example while displaying total cocoa production data, in order to make the large unit more comprehensible for users I chose to use the waffle chart and divide them into smaller groups. Although mapping techniques vary from section to section, typography hierarchy, color scheme and layout structure remain the same to create a smoother learning curve for first-time users.

At the end of each section, I highlighted one of the main takeaways as a summary, then it ends with a question which would open the discussion of the next section. Echoing to the project homepage, endpage adopts the form of a chocolate bar's back packaging. Here the "chocolate label" summarizes credits and acknowledgement information.

Conclusion

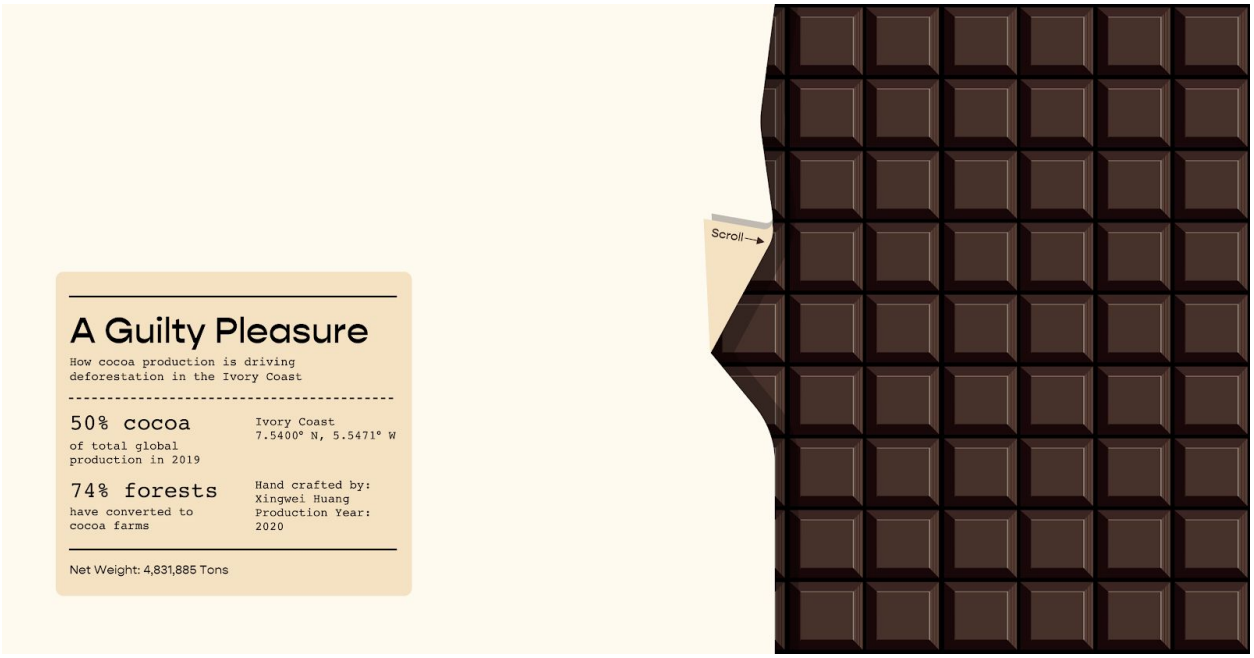
This project aims to study how cocoa production is driving deforestation in Ivory Coast, unveiling the invisible costs we've paid for each pound of chocolate. It also addresses some of the challenges that cocoa cultivation is constantly facing, which are the roots for the deforestation problem. Through aligning and analyzing datasets next to each other, it's evident that there is a significant correlation between deforestation and increase in annual cocoa yields. What's more disheartening is to find that some of the protected forests have been completely turned into a cocoa plantation site in the past decade. Additionally, deforestation and climate change have formed a vicious cycle, each one driving the other faster and creating more challenges for cocoa plantations. Under current farming practices, in order to supply more cocoa beans, it's unavoidable that both deforestation and global warming will worsen.

Because demand for cocoa beans is always on the rise, it's more than urgent to rethink and establish a healthy and sustainable ecosystem for cocoa beans. We can't undo what's already been done, but we can prevent history from repeating again and again. Through identifying each type of deforestation that has taken place during the cocoa cultivation process, we can remedy the problem with potential solutions. One of them is to advocate a better alternative to the monoculture farming method which is agroforestry. Some farming sites have already started testing this method and the results are positive. My hope is that with more and more research being done in multi-functionality comparisons, it could help scientists and decision makers determine long-term strategies which would use plant biodiversity as an actionable lever to adapt to and mitigate climate change. At the same time, in order to strategize for future increases, this sustainable approach can also address the relationship between cocoa plantations and the natural environment. Besides supporting chocolate companies that are dedicated to creating chocolate from deforestation-free cocoa beans, as customers we can also minimize our food waste footprint in acknowledgment of the hardship behind every production.

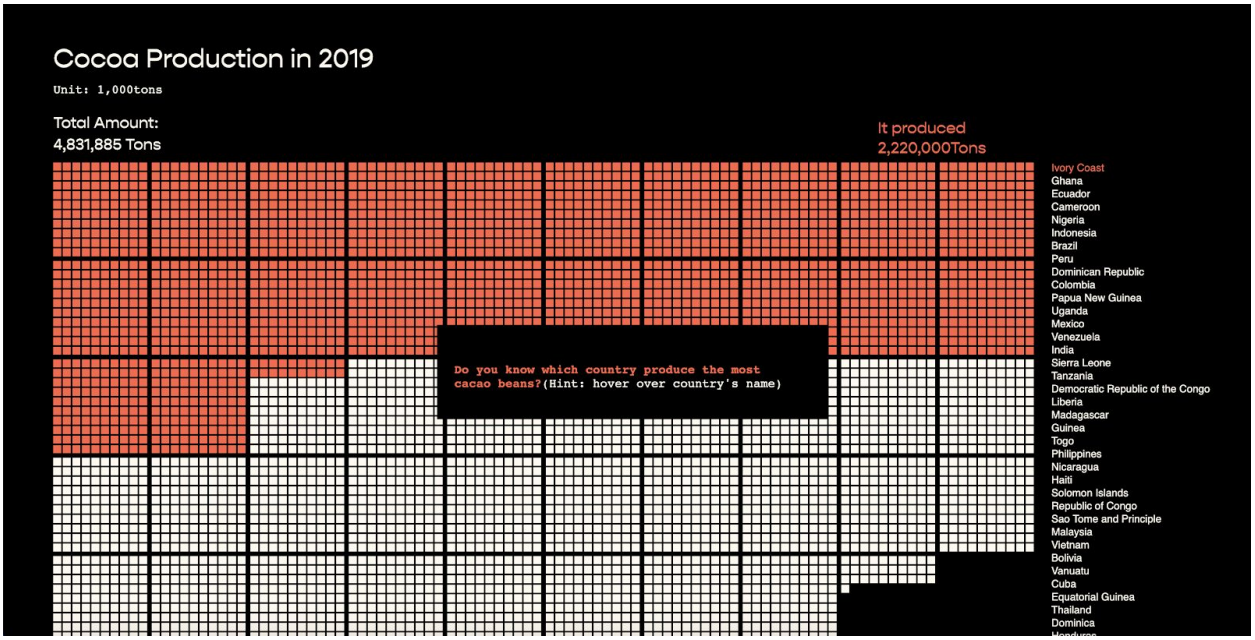
However, the deforestation issue is intricate. Although the Ivory Coast is considered to be the largest supplier for cocoa, their forests cover rate has dramatically dropped during the last few years. The correlation doesn't necessarily suggest that cocoa is the only cause, since they also have large quantities of exports of agricultural products such as coffee and nuts. It would be an overgeneralization to say cocoa is the only factor that accounts for deforestation in the Ivory Coast. Cocoa production only accounts for a bigger percentage of the problem compared to other factors. A sustainable supply chain won't eliminate deforestation completely but would alleviate the current situation and inspire other industries to switch their unsustainable and destructive patterns.

Appendix

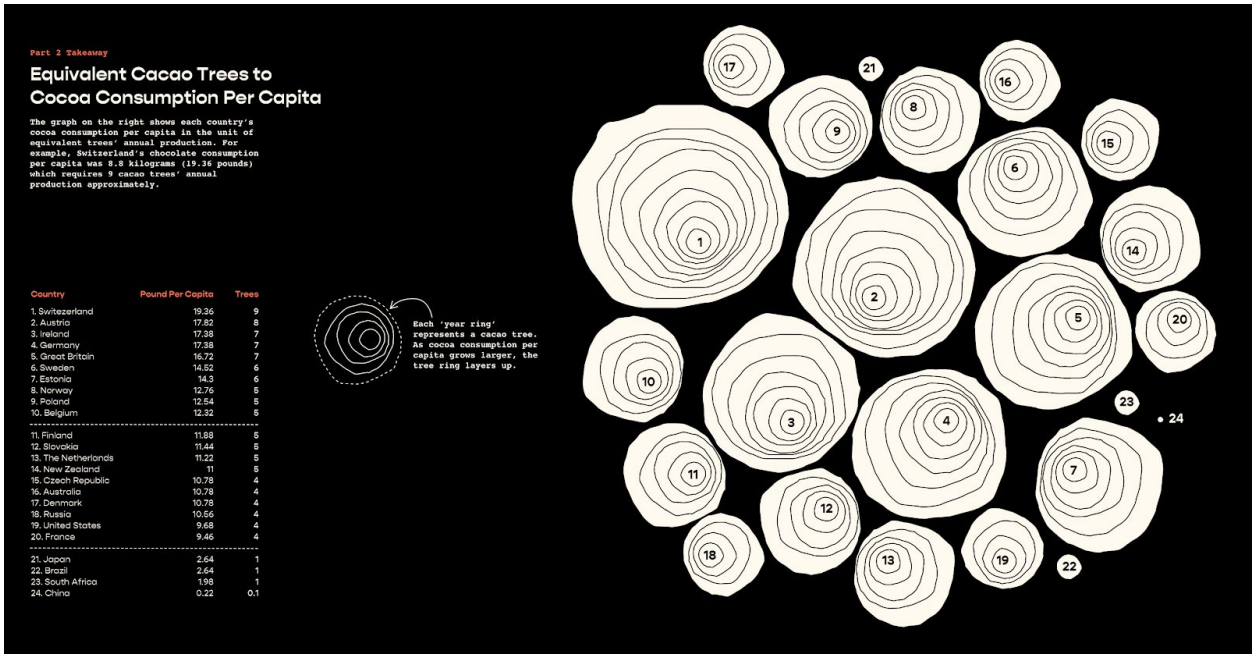
Below are some of the screenshots from my project.



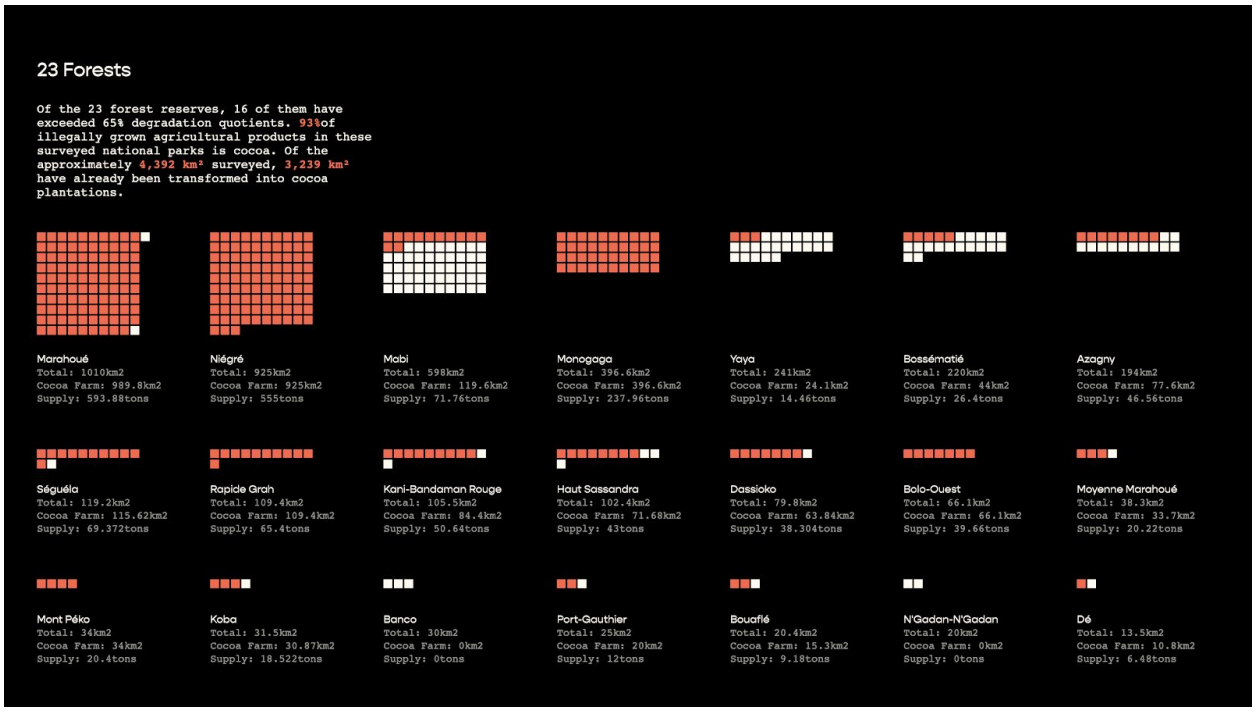
A Guilty Pleasure, homepage



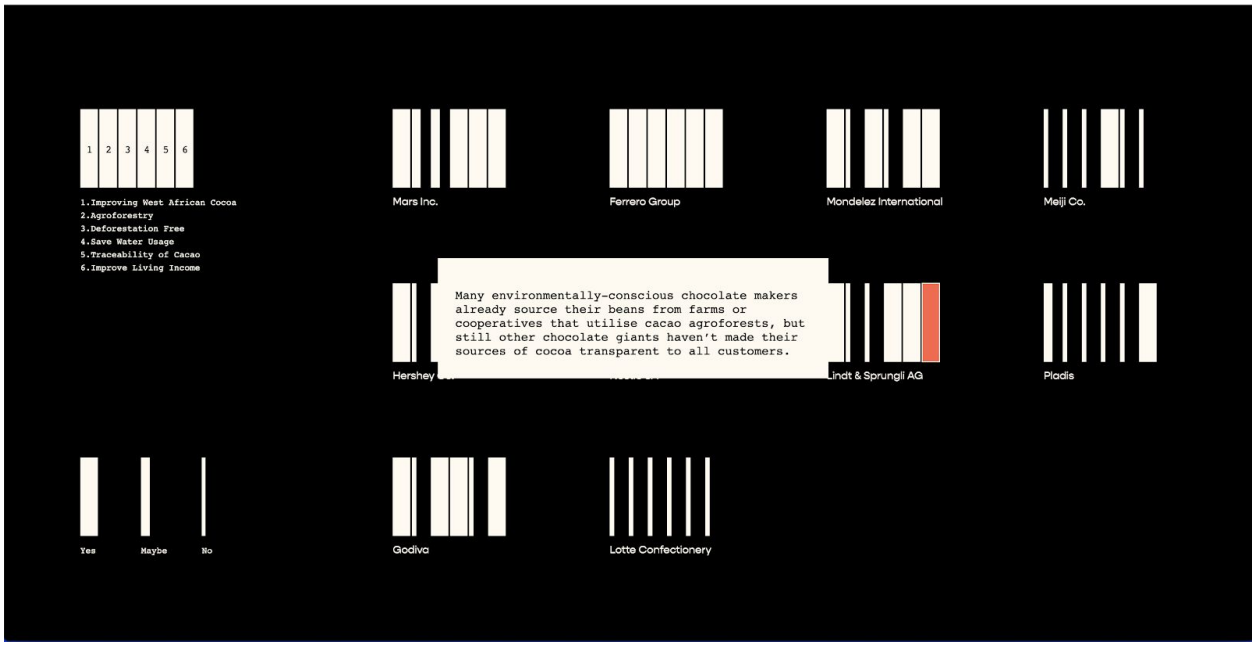
Global Cocoa Production in 2019



Equivalent Cacao Trees to Cocoa Consumption Per Capita



Conversion Rate of Forests into Cocoa Farms



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