An Impact Analysis of a Synthetic Palm Oil:

Outlining a New Approach to Ethical Considerations In the Production of High-Value Chemicals

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Human Practices

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PROJECT SUMMARY

Introduction

This report presents a detailed analysis of the impacts incurred from the introduction of a completely synthetic palm oil to the global markets. It will calculate the costs to the economies of Malaysia and Indonesia where the palm oil industry and its subsidiaries are significant and calculate the benefits it could potentially bring to the prices of crude palm oil and other agricultural commodities to highlight the importance of this project. By assessing the impact of this particular application of synthetic biology we hope to consider the impact on this emerging industry of synthetic biology advances on the global market.

Description Of The Project And The Economies of Malaysia and Indonesia

We are producing a synthetic palm oil using *E. coli*, with the possibility that one day this new synthetic palm oil could potentially meet up with or surpass production of natural palm oil which is extracted from the oil palm, grown mostly in Malaysia and Indonesia. The palm oil industry and its subsidiaries represent significant income for families, particularly those living in rural areas.

Summary Of The Palm Oil Industry

The following is a breakdown of the economies and the palm oil industry in Malaysia and Indonesia, currently the two largest producers of palm oil in the world.

	GDP (2012)	Export Revenue From Palm Oil and Related Products	Population (2012)	Direct Employment in Palm Oil Industry
Malaysia	303.5 Billion USD	25.24 Billion USD	29.24 million	570,000
Indonesia	878 Billion USD	14.5 Billion USD	246.9 million	2 Million

Table 1: The importance of the palm oil industry in Malaysia and Indonesia Figures from: MPOC
The Hindu
World Bank
World Growth

There are currently 5 million hectares of palm oil plantations in Malaysia, it is thought that in the future, however, only 200,000-300,000 hectares will be available for planting **[1].** Because of limited arable land available in the future, if palm oil continues to be purely an organic product, with no advancements in the process of production, future supply of the commodity will only ever achieve half of the global demand **[2].**

-Basiron, Y. (2009). Malaysia Palm Oil Council: Accessible at: http://www.mpoc.org.my/upload/Trends%20and%20Potentials%20of%20Malaysia's%20Plantation%20Sector.pdf
-Martin, K. A. (2012) 'Price war hits Malaysian palm oil exporters' *The Hindu.* October 15th. Accessible at: http://www.thehindu.com/business/Industry/price-war-hits-malaysian-palm-oil-exporters/article3999650.ece
-World Bank. Accessible at: http://www.worldbank.org/
-World Growth (2011). The Economic Benefit of Palm Oil to Indonesia. Accessible at: http://worldgrowth.org/site/wp-content/uploads/2012/06/WG_Indonesian_Palm_Oil_Benefits_Report-2_11.pdf
[1] Tan, M and Sandianto, A. (2013) Asia Palm Oil Sector. Credit Suisse. February 20th. Accessible at: https://doc.research-and-analytics.csfb.com/docView?language=ENG&source=ulg&format=PDF&document_id=1010295291&serialid=6UHVdC%2B6WdYp5XYgDpCLmxS27ROrpcKXR%2B9TvRFXrvw%3D

ANALYSING THE ECONOMIC IMPACT

Cost- Benefit Analysis For A Synthetic Palm Oil

Benefits

The introduction of a synthetically produced palm oil is expected to have beneficial impacts on the global market of the commodity. With particular insight into the history the global market price for the Crude Palm Oil commodity, benefits will be analysed below.

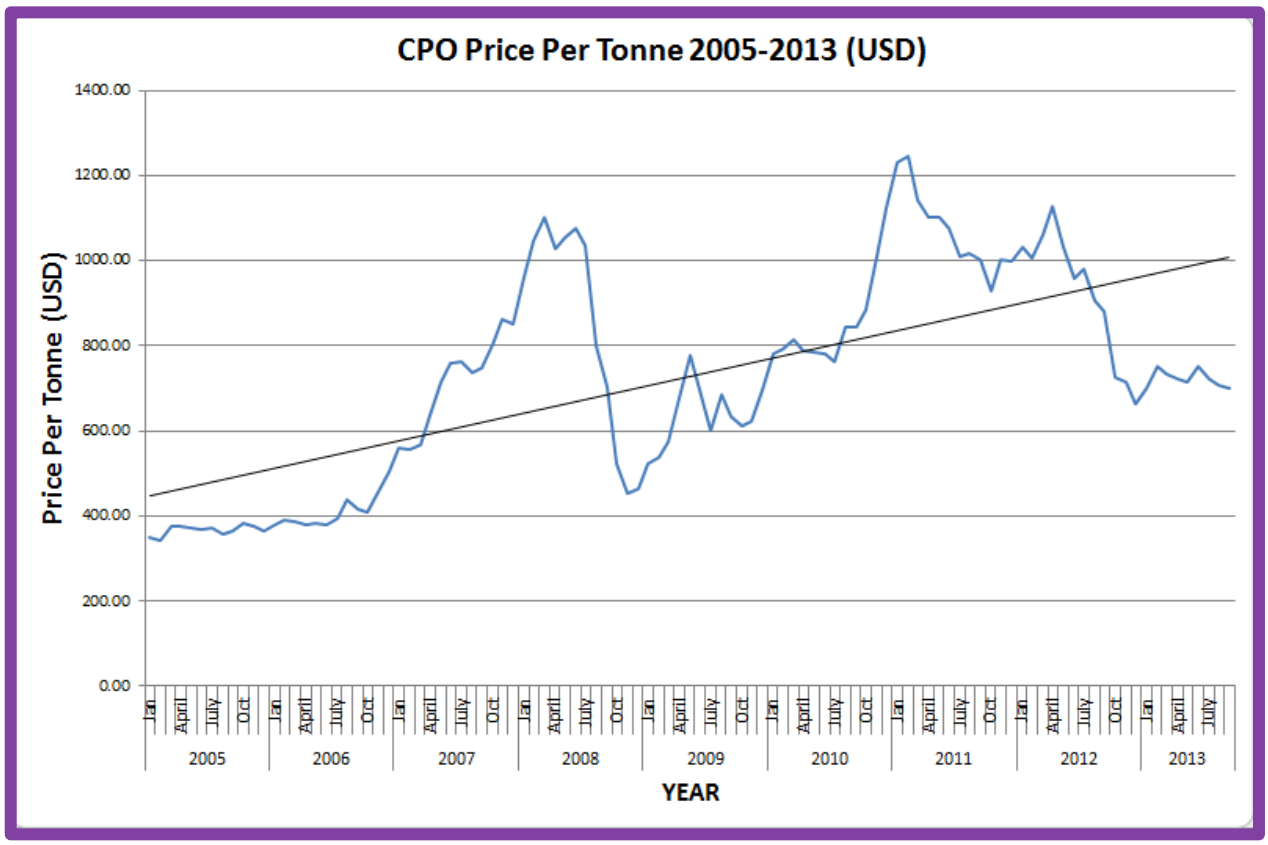

Figure 1: Change in CPO prices over time Values taken from: MPOB

The crude palm oil prices have experienced a general increase from 2005 (Figure 1). What's most prominent are the dramatic pikes in price in 2008 and 2011/2012.

Malaysian Palm Oil Board (2013). Accessible at : http://bepi.mpob.gov.my/index.php/statistics/price/daily.html

In the twelve- month period between June 2007 and June 2008 the price of vegetable oils doubled **[2].** In the end, the price had to be artificially controlled by government interventions: trade quotas and moratoriums were set on biodiesel production amongst other things to limit demand for vegetable oils and return prices to pre-crisis levels **[2].** This highlights the importance of meeting supply with demand. Below is a graphical display of how a mismatch of demand and supply translates into increases in the price of specific commodities.

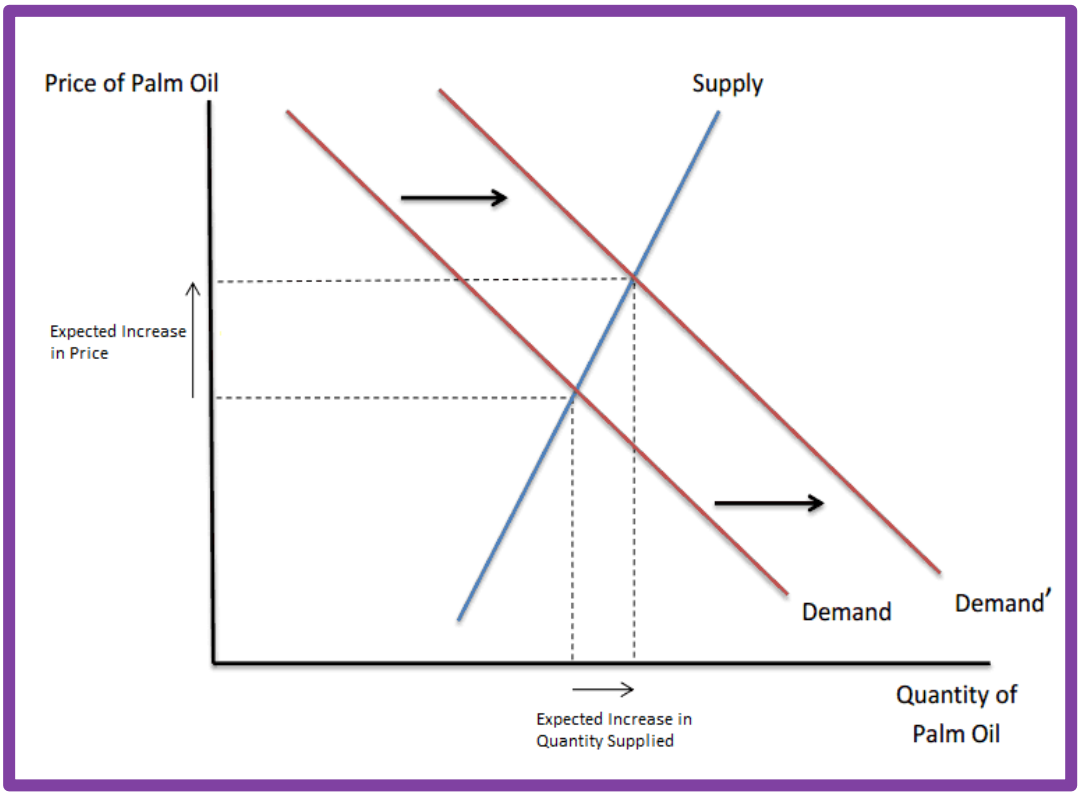

Figure 2: Modelling a shift in demand to a change in price for Palm Oil

The following is an explanation of why the events of 2007/08 and 2011/12 will occur much more exacerbated in the future, *ceteris paribus*. This will highlight the importance and the benefits of the venture.

In 2009, the world consumed 6.5kg of palm oil per capita **[3].** Whilst the global population is increasing year on year, the amount of palm oil consumed is also increasing. Table 2 illustrates how palm oil consumption has changed with a growth in global population.

	World Population ('000,000s)	Global Palm Oil Consumption per Capita (kg)
2009	6,830	6.5
2010	6,920	7
2011	7,000	7

Table 2: Growth in population and global palm oil consumption per capita

Data from: MPOB
Sime Darby Plantatic
World Growth
Worldometers

[3] Food and Agricultural Policy Research Institute (2010). U.S. and World Agricultural Outlook. FAPRI, Iowa. Available at: http://www.fapri.iastate.edu/outlook/2010/, accessed in September 2010

- Abdullah, R. and Wahid, D. 'World palm oil supply, demand, price and prospects: focus on Malaysian and Indonesian palm oil industry. MPOB. Available at: http://www.mpoc.org.my/upload/WorldPalmOil_SupplyDemandPriceProspects_MalaysianIndonesianIndustry_FullReport.pdf
- Sime Darby Plantation. Palm Oil Facts & Figures. Accessible at: http://www.simedarbyplantation.com/upload/Palm-Oil.pdf
- World Growth (2011). The Economic Benefit of Palm Oil to Indonesia. Accessible at: http://worldgrowth.org/site/wp-content/uploads/2012/06/WG_Indonesian_Palm_Oil_Benefits_Report-2_11.pdf

It is predicted that, by the year 2020, the global population will be 7.72 billion **[4]**, working with 7 kg per capita, although this will most likely increase due to factors later discussed, it can be estimated that aggregate supply will be required to increase by 3.9 million metric tonnes in order to meet expected demand/ consumption.

The level at which palm oil will be demanded is also set to increase as a direct result of an increase in aggregate demand of biofuels. By 2018 global usage of vegetable oil in biodiesel will be double that of 2006-08 **[5]**. It's been reported that 'palm oil is the cheapest available vegetable oil' **[6]** and therefore it could be presumed that palm oil represents the most attractive investment for companies involved in the manufacturing of biofuels. Legislation has been put in place by cooperatives to ensure that a certain amount of biofuels compose the universal fuel use. For example, in the EU, under the directive 2009/28/EC, the amount of renewable energy in the transport sector should be 10% for all member states by the year 2020 **[7]**. This generates a high, guaranteed demand for vegetable oil, of which palm oil is the most price competitive.

Commercialising production of a synthetic palm oil won't just have effects on the market for palm oil in terms of prices, we anticipate that other markets will also be affected.

Over the years food prices have increased considerably. Research shows that they are going to continue to increase further over the next 30 years, with some suggesting that we could see food prices triple **[8]**. This is of course down to many contributing factors, but one of significance is the goal to meet biofuel targets, creating a huge demand for palm oil **[9]**. This has led to large volumes of food crops being transferred to biodiesel production, as opposed to being used in food production **[10]**. If palm oil became a synthetically produced substance rather than it being a naturally grown substance, we might see that food prices become a lot more constant as considerably more future deforested land will be used to grow crops for food purposes rather than growing palm oil to be used in biofuel production.

[4] http://www.worldometers.info/world-population/

[5] OECD-FAO (2009), Agricultural Outlook 2009, accessible at: www.agri-outlook.org

[6] ICCT (2013). 'Vegetable oil markets and the EU biofuel mandate'. Accessible at: http://www.theicct.org/sites/default/files/publications/ICCT_vegoil_and_EU_biofuel_mandate_20130211.pdf

[7] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:140:FULL:EN:PDF

[8] Hawkes, S (2013) 'Food prices forecast to treble as world population soars' *The Telegraph*. July 21st. Accessible at: http://www.telegraph.co.uk/finance/personalfinance/consumertips/household-bills/10193903/Food-prices-forecast-to-treble-as-world-population-soars.html

[9] Wiggins, S and Levy, S. (2008). 'Rising food prices: Cause for concern'. Overseas Development Institute. Accessible at: http://www.odi.org.uk/sites/odi.org.uk/files/odi-assets/publications-opinion-files/2555.pdf

[10] Rosegrant, M. (2008). Biofuels and Grain Prices: Impacts and Policy Responses. IFPRI. Accessible at:

Costs

The initiation of the project has the ability to cause negative economic impacts on the countries where the palm oil industry represents a significant element of the economy.

Here, the costs of introducing such a project as this one will be discussed with a particular focus into the effects it could potentially have on the economies of Malaysia and Indonesia; the two largest producers of palm oil in the world.

As discussed earlier in the report, palm oil provides a considerable amount of income for any country involved with the palm oil industry and will continue to do so in the future, provided elements of our venture don't come to full fruition. In 2011, RM80.41 billion (25.24 billion USD) was generated in export revenue from the selling of Malaysian palm oil and related products, including palm kernel oil **[11]**. This level of income is gargantuan and represents over 8.5% of GDP **[12]**, it would be difficult to obtain this level of income elsewhere. The creation of a synthetic palm oil puts this industry at risk as businesses become more conscious of their impacts on the environment in terms of organic palm oil production.

The success of our project may also have an effect on the livelihoods of the plantation workers through loss of employment. Indonesia and Malaysia are leading the way in the global palm oil industry. In these two countries several millions of people rely on this industry for their livelihoods. In Malaysia alone 2.26 million people are depending on the strength of the industry in this country, whether it is direct or indirect **[13]**. With a population of 29.24 million (Table1), an industry which affects the wellbeing of 7.6 per cent of the population can be considered an imperative in the wellbeing of a large proportion of country's population. Similarly, in Indonesia, reports suggest that there could be at least 14 million people, in 3.5 million households, to whom palm oil is a source of income **[14]**. It is therefore important to acknowledge the potential impact creating a synthetically produced palm oil could have on employment in countries like Malaysia and Indonesia where palm oil represents significant employment opportunities.

[11] http://bepi.mpob.gov.my/images/overview/Overview_of_Industry_2011.pdf

[12] http://databank.worldbank.org/data/views/reports/tableview.aspx

[13] Malaysia Palm Oil Council. Accessible at: http://www.palmoilworld.org/sustainability.html

[14] Bahroeny, J. (2009). 'Palm oil as an economic pillar in Indonesia' *The Jakarta Post.* December 2nd 2009. Accessible at: http://www.thejakartapost.com/news/2009/12/02/palm-oil-economic-pillar-indonesia.html

Long-Term Negative Implications

Something which is particularly worrying is the potentially long time it could take the largest palm oil producing countries, such as Indonesia and Malaysia, to overcome the effects that the venture may initially inflict on them.

One thing to assess is how easy it would be for the land used for palm oil prior to the commercialisation of our project to be used for an alternative crop or industry. It was found that changing crop type is not as easy as one would think. For instance, soil used for palm oil plantations often becomes so devoid of nutrients that the only vegetation which is able to grow on the land is weedy grass, and after 25 years the plantations are so unproductive such that they are abandoned for scrubland **[15]**.

Furthermore, chemicals used in the growing process pollute the land and water sources, this could potentially make the area around the plantations unable to sustain any form of vegetation for some time after the plantations have been abandoned **[16]**.

[15] Butler, R. (2006) 'Why is oil palm replacing tropical rainforests? Why are biofuels fuelling deforestation?' *Mongabay.* April 25th. Accessible at: http://news.mongabay.com/2006/0425-oil_palm.html

[16] Rainforest Rescue. Facts about palm oil and rainforests. Accessible at: http://www.rainforest-rescue.org/topics/palm-oil

AN ENVIRONMENTAL IMPACT ANALYSIS OF CURRENT PRODUCTION

Palm oil is used in hundreds of products. It is likely that you have either consumed or used a product today containing palm oil or its constituents, but we, as consumers, rarely think about it or where it comes from. The truth behind its current method of production is devastating.

Problems Inherent in the Current Cultivation of Palm Oil

Currently, rainforest areas the size of 300 football fields are being chopped down every hour in Indonesia and Malaysia to make room for oil palm plantations **[17]**. Forest fires are also deliberately lit in order to clear huge areas of forestland, destroying everything in their path **[18]**. The effects of this mass deforestation are enormous.

Firstly, the destruction of these rainforests is resulting in the rapid extinction of many critically endangered species, the most reported of which being the orangutan **[19]**. Of course, animals aren't the only organisms being wiped out by the palm oil industry. The flora found within rainforests is amongst the most diverse on Earth, with many plants being used for medicinal purposes and to advance medicinal research. Replacing these plants with oil palms results in a massive decrease in biodiversity **[20][21].**

Equally importantly, huge groups of people live in the rainforests of Indonesia. Palm oil companies bulldoze entire villages found within the rainforests, causing indigenous people who have been living in harmony with Nature for generations to flee their homes **[22]**. What's worse, the people living in these villages are then utterly exploited and made to work for the large international investors controlling the plantations, or to hire themselves out for pathetic wages **[23].** Whilst this is abhorrent in itself, it also suggests that the oil palm plantations and their expansions do not entirely contribute to the economies of these countries that the palm oil industry in Malaysia and Indonesia does not entirely support the economies of these countries, as international companies are amongst those profiting the most from this industry.

[17] Rainforest Rescue. http://www.rainforest-rescue.org/topics/palm-oil
[18] WWF Global. 'Orangutans and oil palm plantations: Hanging on- but just barely'. Accessible at: http://wwf.panda.org/about_our_earth/about_forests/deforestation/forest_conversion_agriculture/orang_utans_palm_oil/
[19] Associated Press in Jakarta (2012) 'Rare Sumatran orangutans dying as fires rage in Indonesian swamp forest' *The Guardian.* March 28th. Accessible at: http://www.theguardian.com/world/2012/mar/28/sumatran-orangutans-dying-indonesia-forest-fire
[20] Adventure Life. Medicinal Treasures of the Rainforest. Accessible at: http://www.adventure-life.com/articles/rainforest-medicine-78/
[21] Indonesian Rainforest Foundation. Rainforest Medicinal Plants. Accessible at: http://www.indonesianrainforest.org/indonesian-rainforest/rainforest-medicinal-plants/
[22] Rainforest Rescue (2011). Indonesia: Victims of the Palm Oil Industry. Accessible at: http://www.rainforest-rescue.org/news/3891/indonesia-victims-of-the-palm-oil-industry
[23] Vidal, J. (2013) 'The Sumatran rainforest will mostly disappear within 20 years' *The Guardian.* May 26th. Accessible at: http://www.theguardian.com/world/2013/may/26/sumatra-borneo-deforestation-tigers-palm-oil

Perhaps the most obvious result of deforestation is the reduction in the number of trees, which act as a colossal carbon sink. Eradicating trees in this way dramatically increases the amount of carbon dioxide in the atmosphere, both through the actual process of deforestation and also because fewer trees means less photosynthesis. Furthermore, rainforests are often growing on top of peatlands. Uprooting these trees then leads to the release of the enormous amount of stored carbon contained within the peatland soils into the atmosphere, close to 60 million tons **[24]**. Because of this, tropical deforestation accounts for more global warming pollution than that caused by all of the vehicles on Earth, including planes, combined **[25]**.

Analysing The Impact On The Sumatran Orangutan

Modelling the population change of the Sumatran orangutan

The palm oil industry is predicted to grow continuously for the next couple of decades, thus further deforestation is definitely inevitable. Based on the results obtained from simulations we ran in the program Vortex ("a Monte Carlo simulation of the effects of deterministic forces as well as demographic, environmental, and genetic stochastic events on wild population") **[26]** and using methods from Orangutan Population Biology, Life History and Conservation **[27]** to build our model's baseline, the Sumatran orangutan population decreases when the time elapses. This denotes that the Sumatran orangutan is facing the very real possibility of becoming extinct within the next 45 years.

Let's say deforestation has been halted and the habitats of orangutan remained after 40 years, by referring to figure 2 (FIG2- Appendix) approximately 650 orangutans were predicted to survive. These 650 orangutans were then used in another simulation on the population for the following 100 years.

In the case of figures 3 and 4 (FIG3 & FIG4- Appendix), the orangutan population seems to drop slightly and maintains a certain range of values but there is still the possibility that the population could drop to such a critically low level that any natural or man-made disaster would easily kill the rest of them. The situation is not too optimistic as there is no sign of any growth on the amount of orangutan that the brutal truth of becoming extinct still exists.

[24] Halter, R (2013) 'Rapacious War Against Nature: Indonesian Palm Oil' *The Huffington Post.* February 9th. Accessible at: http://www.huffingtonpost.com/dr-reese-halter/rapacious-war-against-nat_b_2654866.html
[25] UCS USA (2012). Palm Oil and Tropical Deforestation. Accessible at: http://www.ucsusa.org/global_warming/solutions/forest_solutions/palm-oil-and-forests.html
[26] Lacy, R.C. 2000. Structure of the VORTEX simulation model for population viability analysis. Ecological Bulletins 48:191-203
[27] Marshall, A. et. al (2009) Orangutan population biology, life history and conservation. In: Wich, S. A., Utami Atmoko, S. S., Mitra Setia, T., and van Schaik, C. P. (Eds.) 2009. Orangutans: Geographic variation in behavioral ecology and conservation. Oxford University Press. Pp. 311-326

The situation is different if deforestation was stopped after 30 years instead of 40 years. Under the most positive circumstances, 2520 orangutans (FIG4- Appendix) would remain and the population size trend on the simulation suggested the population would stay at a steady level and by chance, the population might downsize to around 800. In contrast, an estimated 1664 orangutans (FIG3- Appendix) would be left in the worst case scenario and the simulations run indicate the possibility of both growing and shrinking of the population size. These models imply that the orangutan population could actually be recovered slowly and that the size could be maintained. In comparison to the simulations ran after 40 years, halting deforestation after 30 years implies a massive difference in terms of the population size and the introduction of our project is therefore believed to be able to contribute in this issue.

At these levels, programs such as rehabilitation of captive orangutans could have a dramatic impact on the survival rate of the Sumatran orangutan. This could be one of the most feasible methods of rescuing the orangutan population. Captive orangutans might not be competitive enough to survive in the wild though, and may not have developed resistance to diseases found in the wild, which would be detrimental to their survival when released. However, thousands of wild orangutans are currently in sanctuaries throughout the world and introducing these back into the wild would dramatically increase this species' chance of survival.

The need for a truly sustainable, cost-effective palm oil

Due to the issues raised above concerning the cultivation of palm oil, and high-profile protests from the likes of Greenpeace **[28],** many multinational companies are making a big push to obtain the palm oil used in their products from sustainable sources. For example Unilever, a company who currently uses 3% of world palm oil, plans to source all of its palm oil from traceable sustainable sources by 2020 **[29]**. Another representative example is Tesco, one of the many major supermarkets aiming to have all of their own-brand products containing only sustainable palm oil by 2015 **[30]**.

So if these companies recognise the negative impact the palm oil industry currently has on the planet, why haven't they already done something about it? The simple answer is profit. At present, certified sustainable palm oil (CSPO) is between 8-15% more expensive than uncertified palm oil **[31]**. CSPO manufacture and use is governed by the Roundtable on Sustainable Palm Oil (RSPO), and 3 supply options are in place **[32]**:

1. *Segregated supply chain*, where the CSPO is physically separated from uncertified palm oil for the entirety of its production, from the certified mill to the end-user. This is a very expensive approach, but ensures that the end-product is CSPO.
2. *Mass balance*, where companies along the supply chain can mix the CSPO with uncertified palm oil, resulting in a less expensive mode of production.
3. *Book & Claim (aka GreenPalm)*, where the growers of CSPO receive a certificate stating so. Consumer goods companies then buy these certificates from the grower, meaning that they support the growth of CSPO.

It is a lot cheaper for companies to just source their palm oil from unsustainable growers than to follow the supply options outlined above.

[28] The Economist (2010). The campaign against palm oil: The other oil spill. Jun 24th. Accessible at: http://www.economist.com/node/16423833
[29] Unilever. Sustainable Living: Our Targets. Accessible at: http://www.unilever.com/sustainable-living/sustainablesourcing/palmoil/ourtargets/index.aspx
[30] Tesco (2013), Sourcing Responsibly: Forest Commodities - Palm Oil. Accessible at: http://www.tescoplc.com/assets/files/cms/Resources/Palm_oil_statement_13052013.pdf
[31] RSPO (2013). Palm Oil in Australia, page 40. Accessible at: http://www.rspo.org/file/PalmOilinAustralia.pdf
[32] WWF Global. What are the sustainable palm oil supply chains? Accessible at: http://wwf.panda.org/what_we_do/footprint/agriculture/palm_oil/solutions/responsible_purchasing/scorecard2

However, are the supply options governed by RSPO actually all that sustainable? Firstly, with mass balance, CSPO and uncertified palm oil can be mixed together by companies. This suggests that companies can source a bit of their palm oil from sustainable places, but top it up with unsustainable palm oil, leading to unsustainable growers still being supported. The same can be said for the book & claim system, where a certificate for CSPO can be bought for as little as US$3 (where the price per metric tonne of crude palm oil, which is supposedly equivalent to one GreenPalm certificate) is US$710 **[33]**, and then the company can still claim to support the trade in sustainable palm oil **[34]**. Additionally, Unilever is actually one of the founding members of RSPO, and is currently one of its chairs **[35]**. Since RSPO is not completely regulated by a neutral party, this raises questions over the group's overall intentions. Shockingly, RSPO does not have in place a "no deforestation" policy **[36],** and recent studies, such as one conducted by Greenpeace **[37]**, indicate that the RSPO is taking inadequate measures to keep track of its members and claims of certified sustainable palm oil growth and use.

If the sustainable palm oil on offer isn't actually sustainable, what more can consumer goods companies actually do? A synthetic biology alternative to palm oil production may be the answer.

[33] Greenpeace (2013). Certifying Destruction. Accessible at: http://www.greenpeace.org/international/Global/international/publications/forests/2013/Indonesia/RSPO-Certifying-Destruction.pdf
[34] Ethical Consumer (2008). Palm oil & RSPO. Accessible at: http://www.ethicalconsumer.org/commentanalysis/environment/sustainablepalmoil.aspx
[35] Unilever. Sustainable Sourcing: Roundtable on Sustainable Palm Oil. Accessible at: http://www.unilever.com/sustainable-living/sustainablesourcing/palmoil/rspo/index.aspx
[36] Monagbay (2013). Nordic energy giant launches 'no deforestation' policy. April 7th. Accessible at: http://news.mongabay.com/2013/0407-neste-palm-oil.html
[37] Greenpeace (2013). Forest fires show RSPO stamp far from 'green'. Accessible at: http://www.greenpeace.org/international/en/news/Blogs/makingwaves/forest-fires-show-rspo-stamp-is-far-from-

Analysing The Impact Of Past Deforestation Prevention Strategies

Policies to try to curb deforestation have largely failed

Despite companies attempting to use more and more sustainable palm oil, government efforts to combat the mass deforestation associated with this industry are, for the most part, failing.

Firstly, Norway offered USD 1 billion to Indonesia if the country suspended the conversion of natural rainforests and peatlands into new oil palm plantations for an initial two years **[38]**. This initiative at first seemed positive, but concerns quickly grew over whether or not the land covered by this moratorium was the most in need of protection **[39]**. Degraded and deforested areas of Sumatra and Central Kalimantan were thought to now be protected, yet the valuable rainforests of Papua remained vulnerable to loggers. In fact, in January 2010, Indonesia's president Susilo Bambang Yudhoyono (SBY) launched a program that would allow Papua's rainforests to be converted into various plantations **[40]**. Another fear was that the $1 billion paid to Indonesia may actually be used to subsidise the logging industry and then allow their actions to be labelled as "environmental initiatives", which would be completely counterproductive **[41]**. Sadly, shortly after Indonesia promised to halt the deforestation of virgin rainforests in 2011, the initial fears were realised. The presidential instruction signed by SBY failed to protect the imperilled secondary forest areas, thus breaking the agreement between Norway and Indonesia **[42]**. However, in May 2013 Indonesia renewed the aforementioned moratorium due to the rising pressure from multinationals such as Unilever and Nestle for a sustainable palm oil. The country's government is to draft a universal map showing virgin rainforests and areas available to oil palm developers. It is hoped that this clarification of protected rainforests will prevent loggers and plantation developers from finding loopholes in the law **[43]**. On the other hand, this arrangement may have widespread negative consequences. Plantation owners are already looking at less-regulated land, such as that in sub-Saharan Africa, for their future business ventures. Therefore this ban on deforestation in one country would simply push the deforestation on to another country. What's more, the same issues with the original moratorium of 2011 are still prevalent with the renewed moratorium of 2013 **[23]**.

[38] Lang, C. (2010). 'Norway and Indonesia sign US$1Billion forest deal'. *Redd- Monitor.* May 27th. Accessible at: http://www.redd-monitor.org/2010/05/27/norway-and-indonesia-sign-us1-billion-forest-deal/

[39] Gilbert, N (2012) 'Indonesian deforestation ban makes slow progress' *Nature.* May 31st. Accessible at: http://www.nature.com/news/indonesian-deforestation-ban-makes-slow-progress-1.10762

[40] Ekawati, A. and Satriastanti, E. (2010) 'Activists say Papua food estate 'not the answer' *The Jakarta Globe.* March 5th. Accessible at: http://www.thejakartaglobe.com/archive/activists-say-papua-food-estate-not-the-answer/362050/

[41] Sandelson, M. (2010) 'Norway's Indonesian anti-deforestation aid 'useless'' *The Foreigner.* November 8th. Accessible at: http://theforeigner.no/pages/news/norways-indonesian-anti-deforestation-aid-useless/

[42] http://www.regnskog.no/languages/english/rainforest-and-climate-change/press-release-indonesia-fails-to-fulfill-its-redd-agreement-with-norway

[43] Einhorn, B., Rusmana, Y. and Listiyorini, E. (2013), 'Indonesia Goes Green to the Dismay of Palm Oil Producers' *BloombergBusinessWeek.* May 30th. Accessible at: http://www.businessweek.com/articles/2013-05-30/indonesia-goes-green-to-the-dismay-of-palm-oil-producers

Next is RSPO. As outlined previously, RSPO has many loopholes enabling palm oil companies to imply that their product is sustainable, when the reality is not so clear. Indonesia adopted its own certification system, Indonesian Sustainable Palm Oil (ISPO). ISPO is controlled by the Indonesian government, and so NGOs are suspicious that the organisation may be a front to allow the oil palm industry in Indonesia to continue business as usual whilst presenting a sustainable front to the outside world **[44]**. ISPO-certified palm oil is also not recognised by European buyers, yet RSPO-certified oil is. This poses a problem in that the ISPO may be scrapped in favour of uncertified palm oil as there is currently no industry demand for ISPO-certified palm oil **[45]**.

Due to the above points many companies, such as cosmetics company Lush, believe that there is no truly sustainable palm oil **[28].** However, in July 2013 the genome of the oil palm was mapped, revealing information on how its yields are regulated **[46].** Replacing other palm oils with genetically enhanced variants boasting larger yields, our project could then be used to supplement their yield to meet world demands. This would maintain a healthy palm oil industry in countries economically dependent on the crop, whilst halting the deforestation of the world's irreplaceable virgin rainforests.

[44] DTE (2011) Indonesian Sustainable Palm Oil Scheme to Speed Up Palm Oil Development. Accessible at: http://www.downtoearth-indonesia.org/node/477

[45] Baskoro, F. M. and Azhari, M. A. (2011) 'Gapki Rejects World Standards, Says Indonesians Must Set Pace' *The Jakarta Globe.* October 9th. Accessible at: http://www.thejakartaglobe.com/archive/gapki-rejects-world-standards-says-indonesia-must-set-pace/

[46] Morelle, R. (2013) 'Genome of oil palm sequenced' *BBC news.* July 24th. Accessible at: http://www.bbc.co.uk/news/science-environment-23418714

MANAGING THE REPERCUSSIONS OF THE VENTURE

Sectors That Could Develop In The Absence Of A Palm Oil Industry

Apart from the palm oil industry, the Malaysian and Indonesian livestock **[47]**, agriculture, services **[48]** and tourism **[49]** industries are well developed and contribute to the national economic growth (GDP). As these industries play important roles in the countries' economies, it is believed that they could replace the palm oil industry in the future if synthetic palm oil is going to overtake natural palm oil.

However, on the other hand, focussed development on these industries bring negative impacts as well like what the palm oil industry has on the environment. One of the inevitable consequences of the livestock industry is clearing of planted lands, such as forests, for cultivating feed crops for the livestocks such as cow and goats. Producing livestock creates waste water or manure which contains mostly nutrients, drug residues, microorganisms, heavy metal and the likes. Over 8% of global water is used in the livestock industry for drinking, washing, processing and disease control **[50]** and the waste water resulted would usually be drained into rivers or seas, affecting the soil fertility and natural water source. Food crops production worsens this problem further by contaminating the soil and underground water source. Chemical fertilisers and pesticides used for increasing yields often contain harmful components which have severe effects on the environment. **[51]**

Tourism is one of the most well developed and profitable industries other than the palm oil business in Malaysia, although it involves many activities like tourism facilities construction and increases carbon footprints **[52]** which disturb the ecosystem. **[53]**

It is assumed that there is enough demand for these new industries as population in both Malaysia and Indonesia is growing fast and more international and local corporations have invested big money to these industries. What's more, the biotech industry is recognized by the Malaysian government as one of the growing sectors which contribute to Malaysian economy, it is now been supported by the government for proper development **[54]**.

[47] FAO (2004), Protein Source for the Animal Feed Industry. Accessible at: http://www.fao.org/docrep/007/y5019e/y5019e0l.htm

[48] Taborda, J (2013) 'Malaysian economy expands 4.3% y.o.y. in Q2. *Department of Statistics, Malaysia.* Accessible at: http://www.tradingeconomics.com/malaysia/gdp-growth-annual

[49] Ibrahim, M. H., Ministry of Tourism Malaysia, Presentation: "Encountering the outflow of trainer and educated national talents in the tourism industry". Accessible at: https://s3-eu-west-1.amazonaws.com/storageapi/sites/all/files/pdf/ibrahim.pdf

[50] http://www2.warwick.ac.uk/fac/sci/lifesci/wcc/research/resources/wateruse/technology/livestock.pdf

[51] Friends of the Earth (2008). Hoofprints: Livestock and its environmental impacts. Accessible at: http://www.foe.co.uk/resource/briefings/hoofprints.pdf

[52] Tourism Vision. Tourism and Climate Change: Emissions. Accessible at: http://www.tourism-climate.de/emissions.htm

[53] Internet Geography. What is the impact of tourism? Accessible at: http://www.geography.learnontheinternet.co.uk/topics/tourism6.html

[54] Frost & Sullivan (2009). 'Overview: Malaysian Agricultural Biotechnology'. *BIOTECHCORP.* Accessible at:

Replacing the palm oil industry with other potential sectors seems feasible but those countries rely heavily on it, providing a large amount of the countries GDP and millions of jobs for the locals for a very long time. It is known to have a short payback period and the tree itself is very productive and efficient. Whilst the newly developed industries discussed above might maintain the economies, there are always extra issues that would restrict their efficiency. For example, in some well-planned plantations and mills, education, health care, electricity/water supply and proper housing are even provided for the workers and families in rural areas. It's not hard to imagine what a massive impact the loss of the palm oil industry would have on these families, they would lose most of these facilities and become unemployed **[55].** When this happens, it is not conservative to predict that Malaysia and Indonesia would face great difficulties in restoring the lives of those reliant on the palm oil industry, and when restoring the economy as well.

The Possibilities Of Patenting

In an attempt to minimise the negative impact the commercialisation of our project would have on the economies of developing countries largely dependent on the palm oil industry, such as Malaysia and Indonesia, our ideas and constructs could be patented. The patenting of products and synthetic organisms developed using synthetic biology is not a new idea, with companies such as Givaudan patenting a microbial route to vanillin for example **[56]**. Another, more recent, example would be the synthetic artemisinin produced by Amyris Biotech, which was a Patents for Humanity winner in 2013 **[57].**

Patenting leads to a protection of the knowledge and technology developed by the researcher, and puts its use, in our case the DNA sequences needed to produce the main components of palm oil, in their hands.

However, there are some ethical issues surrounding the idea of patenting a naturally occurring product or a living organism. Some groups feel that allowing the patenting of synthetic versions of naturally-occurring products could be the first step towards the privatisation of synthetic life forms **[58]** as well as furthering the privatisation of products and processes found within nature **[59]**. These groups feel that nature, and all it has to offer, should not be owned by anyone.

[55] Cheyenne Mountain Zoo. Accessible at: http://www.cmzoo.org/conservation/palmOilCrisis/
[56] Bomgardner, M. M. (2012), "The Sweet Smell of Microbes", *Chemical & Engineering News.* July 16th. Accessible at: http://cen.acs.org/articles/90/i29/Sweet-Smell-Microbes.html
[57] USPTO press release (2013), "U.S. Department of Commerce Announces Patents for Humanity Winners", April 11th. Accessible at: http://www.uspto.gov/news/pr/2013/13-17.jsp
[58] UK Parliamentary Office of Science and Technology (2008). Postnote: Synthetic Biology. Accessible at: http://www.parliament.uk/documents/post/postpn298.pdf
[59] FotE US, CTA & ETC Group. The Principles for the Oversight of Synthetic Biology. Accessible at: http://www.biosafety-info.net/file_dir/15148916274f6071c0e12ea.pdf

Another issue found when considering the patenting of synthetic biology is that, by issuing patents, research development around the area may be hindered due to the restrictions imposed by the legislature **[60].** On the other hand, the use of patents could be done for positive things. The reason that we would theoretically like to patent aspects of our project is to protect the economies of those developing countries reliant on the palm oil industry. The CINVESTAV-IPN-UNAM Team 2012 alluded to the fact that patenting could be used to protect a technology but also then be licensed out to users **[61]**. Therefore within our patent we could write a licence, which would enable these countries to use the technology at a lower rate than other countries, or even for free. We could also give the technology to Malaysian/Indonesian universities or governments, and provide workers there with the skills necessary to work using synthetic biology.

It is clear that the patenting of synthetic biology is a controversial topic, yet we believe that each case must be considered individually. The decision on whether or not a certain idea concerning synthetic biology should be patented must then depend on the case in question.

The Impact Of Patenting

Licensing Of The Venture To An Academic Institution Or Government Body

Should we successfully patent our project and be able to licence it out to another country, the problem of exactly *who* should receive the licence arises. A few options present themselves. The technology could be given to an academic institution, a relevant industry or to the government itself.

When determining which sector to give the licence to, it is necessary to first evaluate the current infrastructure in place within each sector. It is important that the sector receiving the licence would be able to accommodate the technology successfully and perhaps even optimise it further, to get the full benefits of a synthetic alternative to palm oil. Due to the depth of information available around Biotechnology research in Malaysia and Indonesia, we focus here primarily on Malaysia, under the assumption that Indonesia will have similar policies and services available to it.

Several universities in Malaysia have an active research community with some focus on biological research, AIMST offering Ph.Ds in Biotechnology for example **[62].** The presence of postgraduate research in this area implies that the relevant facilities required to carry out biological research must be in place. What's more, Agro-Biotechnology Institute Malaysia (ABI) **[63]** undertakes R&D and commercialisation projects related to agro-biotechnology, often in collaboration with universities. This suggests that, should the licence for our project be provided to a Malaysian university, strong links between the university and Biotechnology institutes would ensure successful implementation of the synthetic palm oil project.

[60] Chan, S. & Sulston, J. (2010), "Patents in synthetic biology", *BMJ.* June 14th. Accessible at: http://www.bmj.com/content/340/bmj.c2984
[61] CINVESTAV-IPN-UNAM Team 2012. Accessible at: http://2012.igem.org/wiki/images/3/36/Intellectual_Property_report.pdf
[62] Education Malaysia. Institution Profile: AIMST University. Accessible at: http://www.mohe.gov.my/educationmsia/profile.php?code=AIMST
[63] Malaysia Agro-Biotechnology Institute. Accessible at: http://www.abi-nibm.my/

Malaysia has a dedicated Ministry of Science, Technology and Innovation (MOSTI), which in turn has a dedicated Biotechnology cluster **[64].** This cluster is a collection of members who each provide services and facilities to help support the programmes under the National Biotechnology Policy. Several of these cluster members appear capable of handling the licence that we would grant them. For example, Genom Malaysia **[65]** is a not-for-profit organisation that works on the generation of new intellectual properties and technologies for economic growth via large-scale collaborations for a range of projects, including those of metabolic engineering. Genom Malaysia seems in good stead to nurture our project should it be licenced out to them.

Therefore we can conclude that Malaysia (and so probably Indonesia too) does indeed have the infrastructure available to it to accommodate projects of this type.

As was established above, both academic institutions and government bodies in Malaysia have the capacity to run a project like this. So which would be the best case scenario?

If the technology was given to a university with an industrial partner (to put the product to market) and then became successful, that university would undoubtedly benefit a lot. The success would generate a lot of income in the form of funding for other projects at the university. It follows that education offered by that specific university would increase quantitatively and qualitatively. However, if the technology was given to the government, in *theory* the profit made from it would be put back into the entire country. If this was the case then the whole of the country and not just one or two universities would benefit.

Upon researching the options, we can conclude that issuing the patent licence out to a government body such as Genom Malaysia, rather than a specific university, would be the best scenario. This is because the facilities are already in place for government bodies to take up the project and get the most out of it. Collaborations with universities could be established via the ABI once the technology is up and running in an attempt to further optimise the processes if the need arises.

[64] Ministry of Science, Technology and Innovation Malaysia. MOSTI Biotechnology cluster. Accessible at: http://www.mosti.gov.my/index.php?option=com_content&view=category&id=42%3Abiotechnology&layout=blog&Itemid=258&lang=en
[65] Genom Malaysia. Accessible at: http://www.genomemalaysia.gov.my/v3/)

Naturally Cultivated Palm Oil and Synthetically Produced Palm Oil Existing in Harmony

According to recent figures, the palm oil industry as it stands today can reach only half of the production rate required to meet global demand for the vegetable oil **[66]**. It follows that the implementation of our project would not have as disastrous effect as one might initially imagine on the economies of countries heavily dependent on palm oil cultivation. In fact, it is quite plausible that a synthetic palm oil could be introduced on the market without causing widespread disruption to the current situation. Since the traditional methods of obtaining palm oil can not hope to meet global demand, even with yet more deforestation taking place, a synthetic alternative could be introduced in order to supplement the supply. This is not the first time a synthetic biology-derived product has been proposed to supplement natural cultivation methods of high-value chemicals. Amyris Biotech originally set out with the aim of synthetically producing around two fifths of the world's demand for the antimalarial artemisinin **[67]**, yet 5 years later and the company announced a move to completely replace the world's supply of the compound **[68]**. Obviously this move was controversial, as no measures were taken to safeguard the livelihoods of the *Artemisia annua* farmers. However, as mentioned previously, the current global demand for palm oil is enormously high and is only about to increase. This suggests that our synthetic method of production could not meet the demand alone, and so both naturally-occurring and synthetically produced palm oil could contribute to the world's supply.

In order to meet world demand for palm oil, already established oil palm plantations could continue business as usual with supplementation from our synthetic palm oil. Current plantations may continue producing palm oil as the damage to the environment has already been done, and clearing the plantations would result in further carbon emissions. Nonetheless, these plantations still pose a threat to the Sumatran orangutan population. Heartbreakingly, orangutans are often shot on sight as pests when they stumble unwittingly into a plantation looking for food or shelter **[18]**, and this illegal behaviour **[69]** needs to be brought completely under control. Whilst already existing plantations could continue to do business, any expansions or further deforestation of the rainforests of Indonesia and Malaysia would be halted in an attempt to preserve the ecosystem. Moreover, recent publications suggest that Malaysia is actually running out of potential plantation area regardless, with just 200,000-300,000 hectares of land thought to be available **[1]**. Halting deforestation would mean that the main party affected by the introduction of our synthetic alternative to palm oil would be the large international investors who routinely grab land and convert it to plantations for huge financial gain, and not the farmers who currently work on the plantations **[23].**

[66] Humanity United. Exploitative labor practices in the global palm oil industry. Accessible at: http://humanityunited.org/pdfs/Modern_Slavery_in_the_Palm_Oil_Industry.pdf
[67] San Francisco Business Times (2008), 'OneWorld Health, Amyris, Sanofi-Aventis sign malaria drug deal', March 3rd. Accessible at: http://www.bizjournals.com/eastbay/stories/2008/03/03/daily3.html
[68] Thomas, J. (2013) 'Synthetic anti-malarial compound is bad news for artemisia farmers' *The Guardian*. April 12th. Accessible at: http://www.theguardian.com/global-development/poverty-matters/2013/apr/12/synthetic-malaria-compound-artemisia-farmers
[69] France-Presse, A. (2012) 'Orangutan 'exterminators' on trial in Indonesia' *The Raw Story.* February 7th. Accessible at: http://www.rawstory.com/rs/2012/02/07/orangutan-exterminators-on-trial-in-indonesia/

Despite the fact that current oil palm plantations would remain in business after the introduction of our venture, the oil palm tree itself only has an economically viable lifetime of 22-25 years **[70].** It follows that plantation owners would have no business once their oil palms have reached too great a height. There is no obvious solution to this problem, yet we propose a few alternatives. Firstly, oil palm growers could be encouraged to consider their future plans as soon as possible, in the hope that once their plantation has run its course they have another source of income to switch to. Another alternative would be that previously cleared, unused land could be converted into plantations whilst leaving virgin rainforest areas intact. Of course, this unused land would have to be healthy and capable of nurturing the oil palms, which may not always be achievable. It may also be possible to reuse the land that a plantation had occupied previously, but the potentially long time it would take for the soils to degrade the pesticides used when cultivating oil palms for many years may mean that this scenario is not feasible for years after a plantation has closed.

Regardless of the fact that synthetic palm oil is unlikely to ever completely replace natural methods of palm oil cultivation, even if it did successfully meet global demand there would potentially still be demand for 'authentic' palm oil. In fact, entire countries may reject a palm oil product derived using synthetic biology. This phenomenon has been seen previously, when a synthetic alternative to a natural product has been introduced to the market. For example, vanillin is a high-value chemical that can now be produced through bacterial fermentation routes yet the 'real' vanilla bean product is still a popular commodity in some circles **[71]**. This implies that there will always be a demand for oil palm plantations, as this is the only route to produce 'authentic' palm oil. Naturally, the massive amount of plantations that currently work to produce the world's supply of palm oil would not be needed if a dramatically reduced corner of the market required naturally-grown product, yet some palm oil business would remain to Indonesia and Malaysia

Excitingly, in July 2013, work was published announcing that the entire oil palm genome had been mapped **[72]**. This is great news as it means that directed research can now be undertaken in an attempt to further improve the yield output of the oil palm tree. As the oil palm already yields 10 times more oil than other major oil crops per hectare **[73]**, optimising its efficiency further will lead to better land usage and a lower rate of deforestation. If collections of these optimised crops became the new generation of oil palm plantations, natural cultivation of palm oil could meet more of the global demand, yet would still unlikely completely meet it. Therefore, we believe that our project could be used alongside these improved oil palms, and together the demand for palm oil could be met with minimal extra cost to the planet.

In short, yes, synthetic palm oil and naturally-produced palm oil can exist in harmony! From the above points it is clear that current methods of palm oil cultivation could never hope to achieve complete coverage of the global demand for this vegetable oil, even if an obscene area of rainforest was further destroyed. A synthetic alternative to palm oil would be the perfect supplement to the palm oil already produced on current plantations.

[70] USDA (2007). Indonesia: palm oil production prospects continue to grow. Accessible at: http://www.pecad.fas.usda.gov/highlights/2007/12/Indonesia_palmoil/
[71] Guy, A. (2012) 'Real Vanilla is Natural, But Natural Vanilla is Fake' *Next Nature.* April 13th. Accessible at: http://www.nextnature.net/2012/04/real-vanilla-is-natural-but-natural-vanilla-is-fake/
[72] Morelle, R. (2013) 'Genome of oil palm sequenced' BBC news. July 24th. Accessible at: http://www.bbc.co.uk/news/science-environment-23418714
[73] American Palm Oil Council. Environmental attributes of oil palm. Accessible at: http://www.americanpalmoil.com/environmental.html

CONCLUSION

This impact analysis report has provided a revolutionary approach to the ethics of synthetic biology. It has provided an insight into the University of Manchester iGEM team's project to produce a synthetic palm oil.

Its focus on the economic effects of bringing a venture like ours into full fruition has given the reader the opportunity to judge for themselves whether it is ethically justified to use synthetic biology in the production of palm oil.

It is our firm belief that if the venture develops into a fully commercialised process, steps can be taken in order to minimize the economic repercussions to the countries where palm oil represents a huge industry. We recognise that this industry employs millions and provides billions of USD in export revenue to countries who are still progressing through developing stages. We must take responsibility for correcting any negative impacts caused by the launch of the venture. However, there will be some detrimental effects which we will be unable to correct.

Yet, it appears to be extremely futile to turn a blind eye to the sheer destruction of some of the world's most diverse habitats happening on a daily basis in the name of palm oil production. It is only set to become much worse if an alternative, more sustainable method of production is not found and fully utilised.

This report has clearly outlined the negative implications that will occur if solutions to present-day problems are not implemented soon. We are strongly convinced that without synthetic biology, there will not be a sustainable future for agricultural commodities.

APPENDIX 1: Population Dynamics Graphs

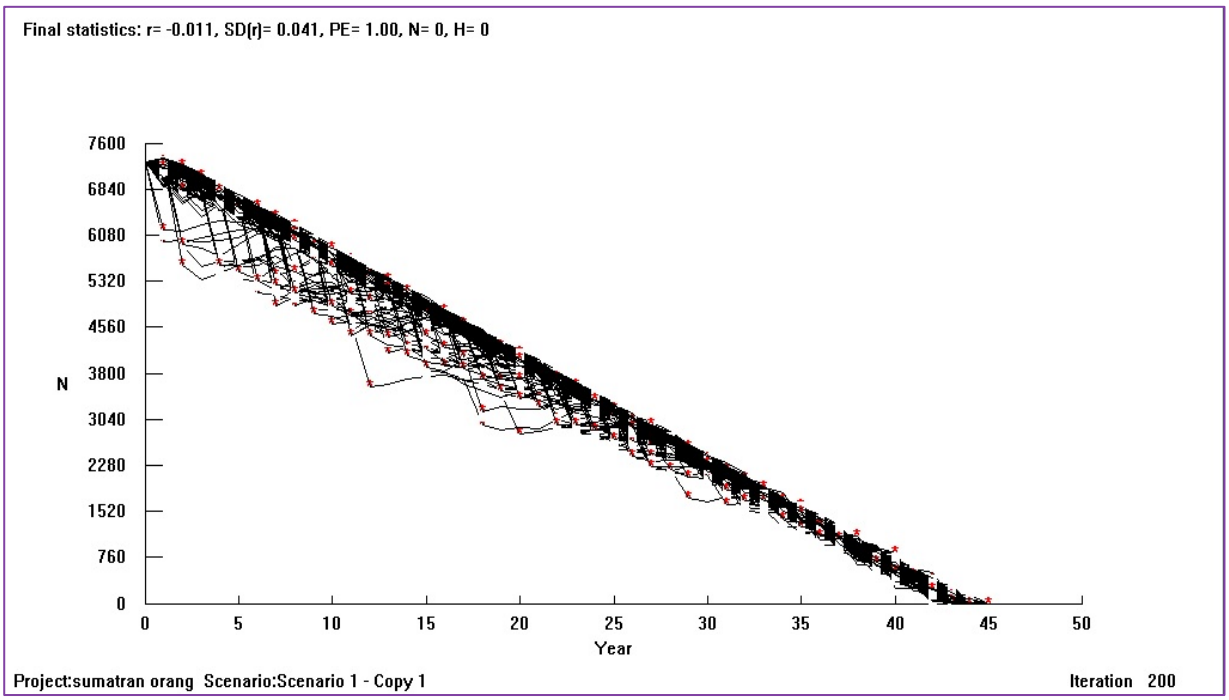

Figure 1: Predicted extinction of orangutans, based on deforestation data analysed on our Human Practices pages (*LINK*) (2.36% annual loss of rainforest coverage). 200 simulations are shown.

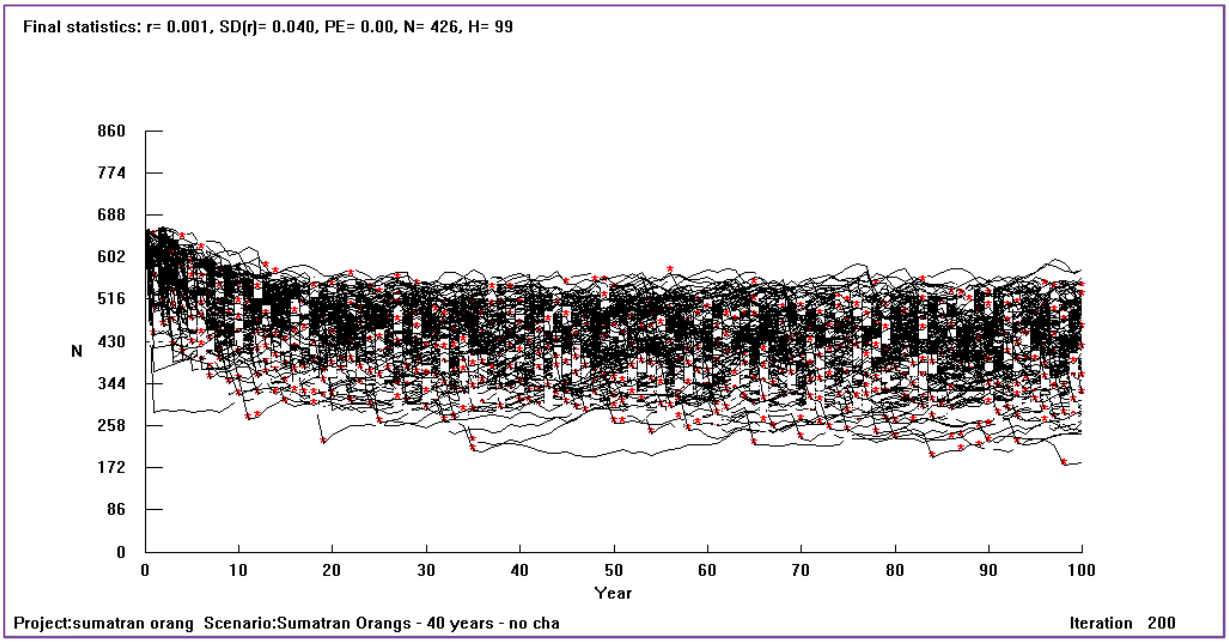

Figure 2: Predicted Sumatran Orangutan population levels, if deforestation in Indonesia was halted after 40 years

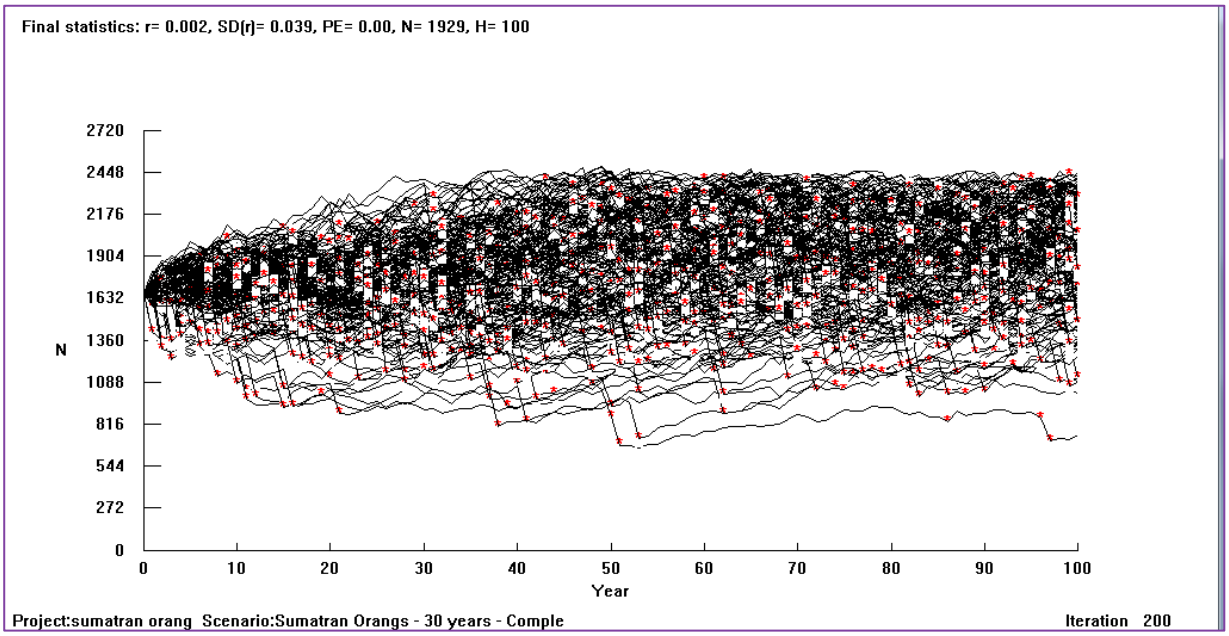

Figure 3: Predicted Sumatran Orangutan population levels, if deforestation in Indonesia was halted after 30 years and populations at this point were at the worst case scenario level indicated by previous simulations (1664 individuals).

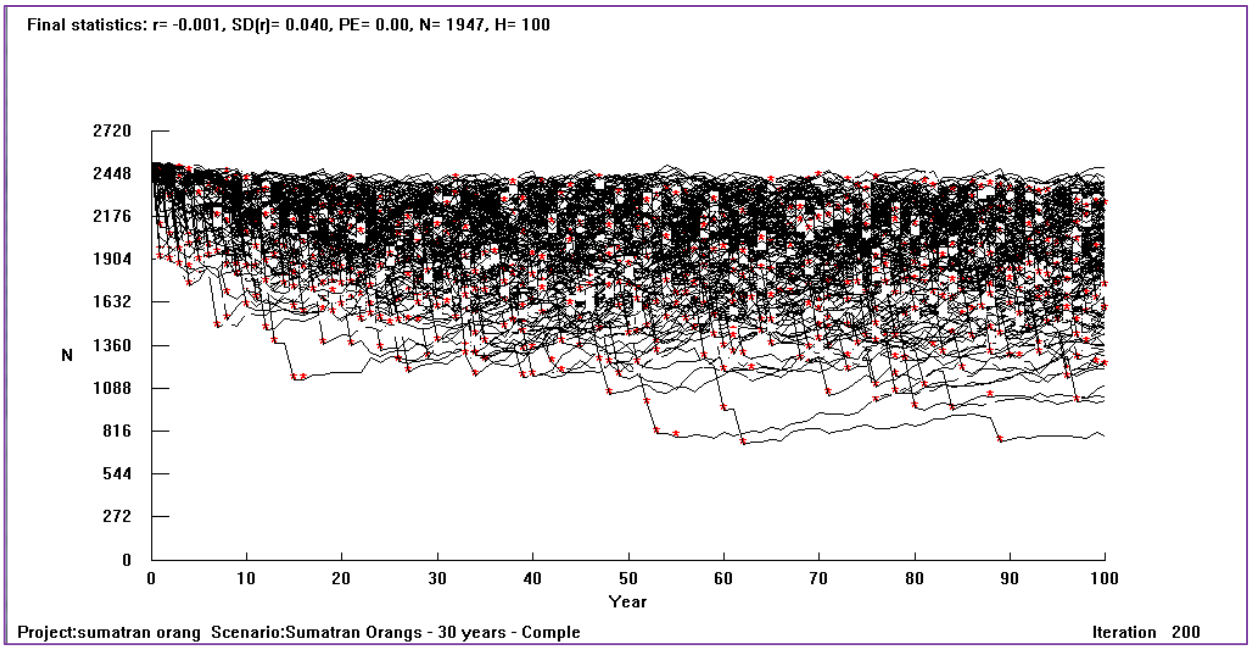

Figure 4: Predicted Sumatran Orangutan population levels, if deforestation in Indonesia was halted after 30 years and populations at this points were at the best case scenario level indicated by previous simulations (2520 individuals)

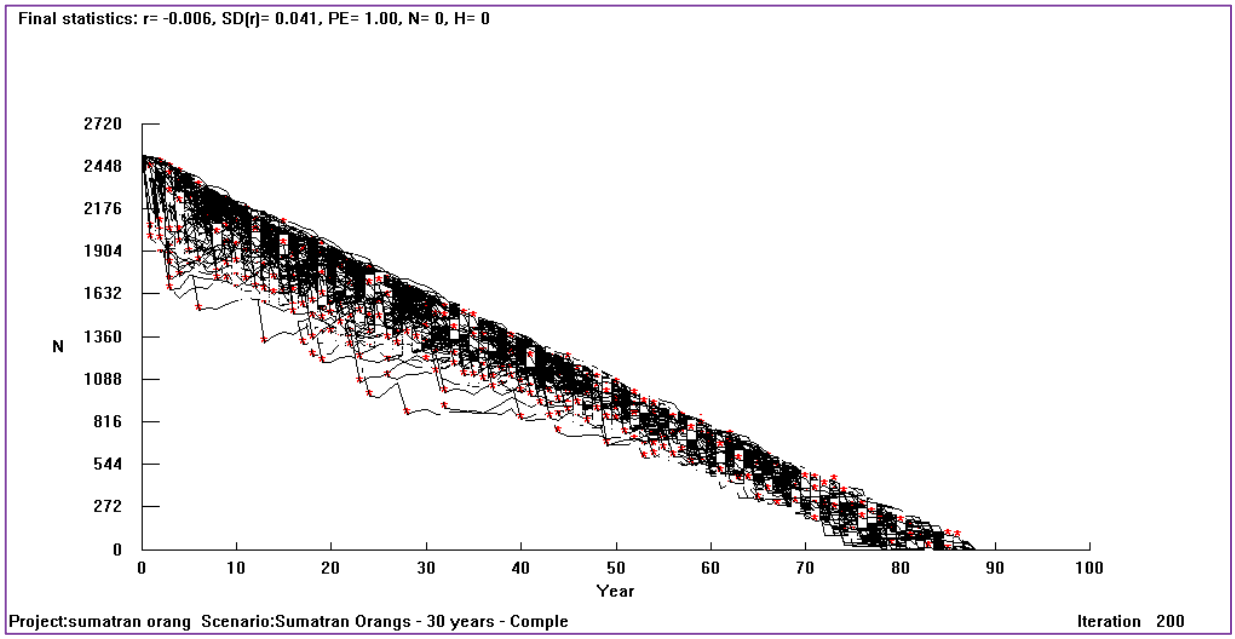

Figure 5: Predicted extinction of Sumatran Orangutan, if annual loss of rainforest coverage could be halved (1.18%) in 30 years, with an initial population size of 2520 individuals

APPENDIX 2: SPONSORS

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