Title: Rainforests and Palm Oil

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Module Summary

In this module, we investigate the impact of palm oil production on the Borneo rainforest and produce mathematical models to describe the growth of palm oil production.

Informal Description

First, students create an exponential function and logistics function while walking through the mathematical modeling process. Students then make predictions with their models and evaluate the effectiveness of the functions created. After analyzing the problem mathematically, students will complete discussion questions to research the pros and cons of palm oil production, the economic impacts of the current practices, how palm oil impacts their own lives, sustainabile initiatives currently being implemented. Using the information calculated and gathered from research, students will argue their view of palm oil production.

Goals

As a result of this module students will:

1. Be able to develop an exponential model given data
2. Be able to calculate and interpret with an exponential model
3. Understand mathematical modeling is a cyclical process requiring models to be analyzed, adapted and updated
4. Be able to create a logistics model given data and a carrying capacity
5. Be able to calculate and interpret using a logistic model
6. Complete research on specific topics, using and documenting creditable sources.
7. Use information gathered during research to formulate and communicate a viewpoint.

Math Topics

Exponential functions; logistic functions; mathematical modeling; math and social justice

Other Subject Areas

Sustainability; palm oil; current events; social justice; opposing viewpoints; digital literacy; resource evaluation; research; critical thinking; and communicating ideas

Target Audience

College Algebra

Prerequisite Math

High school algebra II

Required Technology

Graphing calculator or Desmos; internet access

Student Resources

Key Sustainability Issues in the Palm Oil Sector
http://siteresources.worldbank.org/INTINDONESIA/Resources/226271-1170911056314/Discussion.Paper_palmoil.pdf

Which Everyday Products Contain Palm Oil
https://www.fda.gov/Food/IngredientsPackagingLabeling/FoodAdditivesIngredients/ucm115326.htm

Products Containing Palm Oil
https://a-z-animals.com/palm-oil/products/

What is Palm Oil?
http://www.mpoc.org.my/Palm_Oil.aspx
About MPOC
http://www.mpoc.org.my/Corporate_Profile.aspx

Citations

Ahlenius, Hugo. "Extent of deforestation in Borneo 1950-2005, and projection towards 2020." *Last Stand of the Orangutan, Rapid Response Assessment*. GRID-Adrenal, 2007. http://www.grida.no/search?query=extent+of+deforestation+in+borneo+1950+2005+and+projection+towards+2020. 26 May 2018.

Crabtree, Steve. "Opinion Briefing: Indonesia's Economic Emergence." *Gallup*. 13 May 2013. https://news.gallup.com/poll/162848/opinion-briefing-indonesia-economic-emergence.aspx. 26 May 2018.

Gibson, Luke. "Towards a More Equal Indonesia." *Oxfam Briefing Paper*, Oxfam GB for Oxfam International February 2017, Oxford, UK (1-19). https://www.oxfam.org/sites/www.oxfam.org/files/bp-towards-more-equal-indonesia-230217-en_0.pdf. 26 May 2018.

Phelps, Glenn and Steve Crabtree. "Worldwide, Median Household Income About $10,000." *Gallup*. 16 December 2013. https://news.gallup.com/poll/166211/worldwide-median-household-income-000.aspx

Rain Forests and Palm Oil

The island of Borneo is divided between three nations, Brunei, Malaysia and Indonesia. The Indonesian portion is the largest. Borneo is the largest producer of palm oil, which is used in foods, cosmetics, detergents, and biofuel. To keep up with demand for the oil, Borneo has been logging rain forests and burning the logged areas to allow for the creation of oil palm plantations. This results in the loss of rain forests while producing large amounts of CO_2. Indonesia is now the third largest producer of CO_2 emissions due largely to the increase in palm oil production.

To determine what will happen in the future if the current trend continues, we must first create a mathematical model of the increase in palm oil production. The table below gives the production of palm oil in Indonesia (mostly in Borneo) in five-year increments since 1965. Each production number, or y-value, is in thousands of metric tons. To make it easier to plot the data and find a mathematical model we will translate all of the x-values, which represent years since 1965. So, the first point, showing the production of palm oil in 1965, will become (0, 174).

First Model: Exponential

Building the Model

1. Fill in the second column in the table below with the translation used and the translations of each year.

Palm Oil Production 1965 - 2005

Year x		**Indonesian Production** y	**Average Value of** b
1965		174	
1970		248	
1975		434	
1980		752	
1985		1280	
1990		2650	
1995		4850	
2000		8300	
2005		15000	

Since the growth in production was slow at the beginning and fast toward the end of the period of time under consideration, we suspect an exponential function model $y = a \cdot b^x$ **will work. To see if this suspicion is correct, we start with the assumption that the rate of change is the same for each year in each 5-year period.**
For example, if the yearly rate of change is *b* during the first 5-year period, then the production in 1966 will be $174 \cdot b$**, the production in 1967 will be** $174 \cdot b \cdot b = 174b^2$**, etc. until 1970 when the production will be** $174b^5 = 248$**.**

2. Solve $174b^5 = 248$ for *b* to obtain the average value of *b* for this 5-year period. (Note: Leave your answer in radical form.)

Recall that radicals can be written as fractional exponents. In particular, $\sqrt[5]{x} = x^{1/5}$.

3. Use a calculator to evaluate $b = \sqrt[5]{\frac{248}{174}}$ by entering $(248/174)\wedge(1/5)$ in the calculator. Round off the answer to the nearest thousandth and enter this in the last cell ("Average Value of b" column) of the table above, in the year 1970 row.

Since the data is shown in 5-year increments, we can estimate the yearly rate of change by taking the fifth root of the ratio of the current and previous production numbers.

For example, the estimate of *b* for the second 5-year period is $b = \sqrt[5]{\frac{434}{248}}$.

4. Estimate the value of *b* to the nearest thousandth for each 5-year period and record the estimates in the table.

5. Look at the values of *b* you calculated and recorded in the table on the previous page.
   a. Are these estimates of *b* relatively close to each other?

   b. If they are, an exponential function model will work. Will an exponential model be a good choice to model the growth in palm oil production?

To find our model we need values for the two parameters *a* and *b* for an exponential function model $y = a \cdot b^x$.

6. Look again at the table on the first page. What is a good choice for the value of *b* in our exponential model? Justify your choice.

   b = _____

   Reason for choice:

7. Next, we need to know the value of the parameter *a*, the initial value of the function. What is the initial production value (the value corresponding to a translated *x*-value of 0)?

   a = _____

8. Use your values for *a* and *b* to write an exponential function model $y = a \cdot b^x$ for the data. Note, the exponent will not be *x*, but the *translation* you used to get the second column.

   Function Model: _____

Predicting with the Model

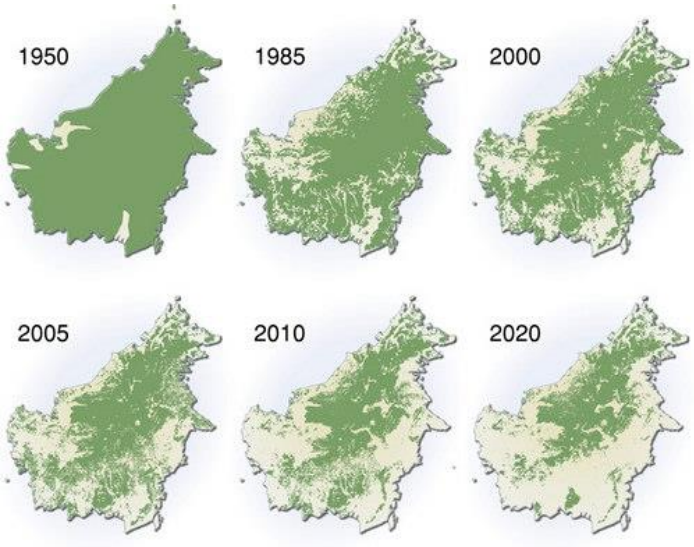
9. Use your model to predict the palm oil production this year if this trend continues. Show how you found your prediction.

10. Use your model to predict the year in which palm oil production will reach 100,000 thousands of metric tons, if the trend continues. Show how you arrived at your answer.

Reflecting on the Model

11. What does it mean for the environment and global warming if the demand (and production) for palm oil continues to grow at the same rate? Explain your thinking.

The following pictures show the amount of rain forest on Borneo for various years.



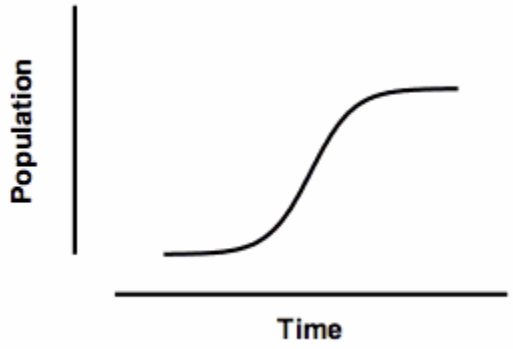
Ahlenius, Hugo. "Extent of deforestation in Borneo 1950-2005, and projection towards 2020." *Last Stand of the Orangutan, Rapid Response Assessment*. GRID-Adrenal, 2007. http://www.grida.no/search?query=extent+of+deforestation+in+borneo+1950+2005+and+projection+towards+2020. 26 May 2018.

12. If palm oil production continues to grow at an exponential rate, what will happen to the rain forest?

13. Use your answer to #12 to explain why an exponential model for the production of palm oil on Borneo will not produce an accurate model in the future.

Second Model: Logistic

If you have data which grows approximately exponentially at the beginning but then the rate of growth slows and eventually approaches a horizontal asymptote (see the curve below), a logistic function may be the appropriate model.



Note: This is typical of mathematical modeling; one model is replaced by a second, more complicated model, which provides a better match to the available data.

A logistic function has the general form: $$y = \frac{L}{(1+be^{kt})}$$

where *L* is the carrying capacity, the maximum possible output value, and *b* and *k* are constants determined by the data being modeled.

Building the Model

In order to find a logistic equation model for our palm oil production data, we must first estimate the maximum palm oil production possible for the island of Borneo. As often happens in modeling, we will make an assumption in order to get a reasonable estimate of the maximum palm oil production. We will assume the percent of former rainforest used for palm oil production remains constant over time. In 2005 only 50.4% of the rainforest remained (so 49.6% of the former rainforest had be deforested).

1. Use a proportion, and our data on palm oil production from the table on the first page, to estimate the palm oil production if 100% of the rainforest has been deforested for agricultural purposes. This will be our carrying capacity *L*. Show the proportion you used.

2. Replace the L in the general form of the logistic function with the value you found above. Also, replace the t in the exponent by the translation we used in the data table to convert the years to years since 1965. We can find one of the remaining parameters in this equation by replacing x with 1965 and y with the palm oil produced that year and solving the resulting equation for the parameter b. Find the value of b for our logistic model. Show all work.

3. Replace b in the general form of the logistic function. Use another (x, y) pair from the table to replace x and y in the new formula. Solve the resulting equation for the parameter k.

4. Write the equation for our logistic model for palm oil production in Indonesian Borneo since 1965.

Predicting with the Model

5. Use your model to predict the palm oil production this year if this trend continues. Show how you found your prediction.

6. Use your model to predict when the palm oil production will reach 30,000 thousands of metric tons.

Reflecting on the Model

7. Describe the assumptions the logistic model is built upon.

8. Describe, in your own words, what the model shows in the context of the problem. What does the model tell us about the demand (and production) of palm oil if current trends continue? What does the carrying capacity mean in terms of the environmental impacts of such production?

9. Is the final model you created perfect? How so or why not? Provide evidence to support your conclusion.

10. If you wanted to further refine the model, what extra information might you include? How would you incorporate this information into the model? How would the extra information change the final model you created above?

Discussion Questions

Answer the following questions. Write your answers in complete sentences and provide citations for any research you include.

Palm Oil: The Negatives

Discuss the negative impacts of palm oil production. One possible resource is Key Sustainability Issues in the Palm Oil Sector

1. Consider the growth of palm oil usage, the human population, and the in-context meaning of the carrying capacity used in your logistic model. The model you created shows a carrying capacity, and therefore a leveling off of palm oil production.
    a. From a global perspective, what do you predict current and future palm oil productions trends will look like?
    b. Are there other areas of the world suited for palm oil plantations?
    c. What impact does the interaction between the palm-oil industry and rainforests on Borneo have on other rainforests worldwide?
2. What are some of the direct and subsequent environmental outcomes resulting from deforestation for palm oil production?
3. What are some of the other impacts of producing palm oil, besides environmental consequences?

Palm Oil: Only Bad?

4. Benefits of palm oil
    a. What are some of the benefits of palm oil? State the information you find and cite the sources you use.
    b. Research some of the benefits listed on this website: What is Palm Oil? List some of the information you find.
    c. Then check out the page About MPOC on the same website. State what you learn from this "About" page.
    d. Which information do you trust more, the research you first found, or the information on the MPOC website. Why?

Palm Oil: Economic Impacts

According to Gallup, the median annual per-capita income in the USA is $15,480. The median annual per-capita income in Indonesia is $541 (Gallup 2018).
Also, "Indonesia's steady GDP growth since the Asian financial crisis of the late 1990s has earned it widespread consideration among the next group of rising economic powers" (Crabtree 2013).

5. Indonesia is a very poor country and its inhabitants need the money they make from palm oil. The cost of living on Borneo is higher, while the income is slightly lower on Indonesian Borneo. Consider palm oil production and the economic growth in Indonesia from the point of view of a palm oil farmer. Write a a short reflection from a palm oil farmer's viewpoint.

Consider the following information:

> "In the past two decades, the gap between the richest and the rest in Indonesia has grown faster than in any other country in South-East Asia. The four richest men in Indonesia now have more wealth than the poorest 100 million people" (Gibson 1).
>
> "Low wages and insecure work for those at the bottom further compounds inequality and prevents workers from lifting themselves out of poverty. Unequal access between rural and urban areas to infrastructure such as

electricity and good quality roads compounds spatial inequalities. A concentration of land ownership in the hands of big corporations and wealthy individuals means that the benefits of land ownership accrue to those at the top, at the expense of the rest of society" (Gibson 2).

"Lack of access to land is another factor contributing to inequality. On average, a smallholder farmer in Indonesia controls less than a quarter of a hectare of land, which does not produce sufficient crops to sustain their family. 105 In contrast, according to research conducted in 2015 by Indonesian NGO Transformasi untuk Keadilan (TuK) and economic research consultancy Profundo, 106 just 25 large business groups control 51 percent of the country's 5.1m hectares of oil palm plantations; an area equivalent to almost half the size of Java. Five 57% of the rural road network is in poor condition Just 25 large business groups control 51 percent of the country's 5.1m hectares of oil palm plantations 19 companies have holdings exceeding 300,000 hectares each. A concentration of land ownership in the hands of big corporations and wealthy individuals means that the benefits of land ownership accrue to those at the top and are not shared equally. Unequal access to land drives wider inequality" (Gibson 18-19).

Gibson, Luke. "Towards a More Equal Indonesia." Oxfam Briefing Paper, Oxfam GB for Oxfam International February 2017, Oxford, UK (1-19). https://www.oxfam.org/sites/www.oxfam.org/files/bp-towards-more-equal-indonesia-230217-en_0.pdf

6. How might the view of an average palm oil farmer differ from someone within the Indonesian government?

Palm Oil: Personal Contribution

Research some of your favorite products. Try this website: Which Everyday Products Contain Palm Oil?
Then, find a few products you use everyday that include palm oil. Try this website: US FDA Food Additives & Ingredients Database

7. What did you learn about everyday products? Provide examples from the websites above.
8. How much do you contribute to the growing demand of palm oil?
    a. What changes to your personal life can you make?
    b. How likely are you to make such changes?

Palm Oil: Global Initiatives

9. What organizations are working on the palm oil production problem?
    a. What steps are these organizations currently taking to reduce the demand and production of palm oil?
    b. What are some other things *you* can do to help reduce the local/national/global demand for or production of palm oil?
    c. How can you convince others to also make changes?

Reflection

10. Should we try to reduce the demand for palm oil? Justify your answer in your response using your model and the information you considered above.
11. Why is this topic important to you or why should it be important to you?
12. After completing this activity has your view of this topic changed? How so, or why not?

Rain Forests and Palm Oil

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To determine what will happen in the future if the current trend continues, we must first create a mathematical model of the increase in palm oil production. The table below gives the production of palm oil in Indonesia (mostly in Borneo) in five-year increments since 1965. Each production number, or y-value, is in thousands of metric tons. To make it easier to plot the data and find a mathematical model we will translate all of the x-values, which represent years since 1965. So, the first point, showing the production of palm oil in 1965, will become (0, 174).

Discuss the background information provided in the student worksheets. Ask students to contribute information they already know about Borneo, palm oil, deforestation, etc.

First Model: Exponential

Building the Model

1. Fill in the second column in the table below with the translation used and the translations of each year.

Palm Oil Production 1965 - 2005

Year x	**Translation** $x - 1965$	**Indonesian Production** y	**Average Value of** b
1965	1965 – 1965 = 0	174	From #16 & #17
1970	5	248	1.073
1975	10	434	1.118
1980	15	752	1.116
1985	20	1280	1.112
1990	25	2650	1.157
1995	30	4850	1.128
2000	35	8300	1.113
2005	40	15000	1.126

Since the growth in production was slow at the beginning and fast toward the end of the period of time under consideration, we suspect an exponential function model $y = a \cdot b^x$ will work. To see if this suspicion is correct, we start with the assumption that the rate of change is the same for each year in each 5-year period.

For example, if the yearly rate of change is *b* during the first 5-year period, then the production in 1966 will be $174 \cdot b$, the production in 1967 will be $174 \cdot b \cdot b = 174b^2$, etc. until 1970 when the production will be $174b^5 = 248$.

2. Solve $174b^5 = 248$ for *b* to obtain the average value of *b* for this 5-year period. (Note: Leave your answer in radical form.)

$$b = \sqrt[5]{\frac{248}{174}}$$

$$b = \sqrt[5]{\frac{124}{87}}$$

Recall that radicals can be written as fractional exponents. In particular, $\sqrt[5]{x} = x^{1/5}$.

3. Use a calculator to evaluate $b = \sqrt[5]{\frac{248}{174}}$ by entering $(248/174)\text{^}(1/5)$ in the calculator. Round off the answer to the nearest thousandth and enter this in the last cell ("Average Value of b" column) of the table above, in the year 1970 row.

$$\sqrt[5]{\frac{124}{87}} \approx 1.073$$

Since the data is shown in 5-year increments, we can estimate the yearly rate of change by taking the fifth root of the ratio of the current and previous production numbers.

For example, the estimate of *b* for the second 5-year period is $b = \sqrt[5]{\frac{434}{248}}$.

4. Estimate the value of *b* to the nearest thousandth for each 5-year period and record the estimates in the table.

$\left(\frac{434}{248}\right)^{\frac{1}{5}}$ $\left(\frac{752}{434}\right)^{\frac{1}{5}}$ $\left(\frac{1280}{752}\right)^{\frac{1}{5}}$ $\left(\frac{2650}{1280}\right)^{\frac{1}{5}}$ $\left(\frac{4850}{2650}\right)^{\frac{1}{5}}$ $\left(\frac{8300}{4850}\right)^{\frac{1}{5}}$ $\left(\frac{15000}{8300}\right)^{\frac{1}{5}}$

Decimal approximations recorded in table above

5. Look at the values of *b* you calculated and recorded in the table on the previous page.
   a. Are these estimates of *b* relatively close to each other?
   Relatively close; range is 0.084; average is 1.118; standard deviation is 0.023
   Outliers:
   Lower fence = 1.1125-1.5*(1.127-1.1125) = 1.09075 > 1.073
   Upper fence = 1.127+1.5*(1.127-1.1125) = 1.14875 < 1.157

   b. If they are, an exponential function model will work. Will an exponential model be a good choice to model the growth in palm oil production?
   It will work; not all points will fit exactly on the curve; good approximation

To find our model we need values for the two parameters *a* and *b* for an exponential function model $y = a \cdot b^x$.

6. Look again at the table on the first page. What is a good choice for the value of *b* in our exponential model? Justify your choice.

b = ____1.117_____

Reason for choice:
Mean = 1.117875
Median = 1.117
Median because outliers

7. Next, we need to know the value of the parameter a, the initial value of the function. What is the initial production value (the value corresponding to a translated x-value of 0)?

   a = _____174_____

8. Use your values for a and b to write an exponential function model $y = a \cdot b^x$ for the data. Note, the exponent will not be x, but the *translation* you used to get the second column.

   Function Model: _____$y = 174 \cdot 1.117^{(x-1965)}$_____

Predicting with the Model

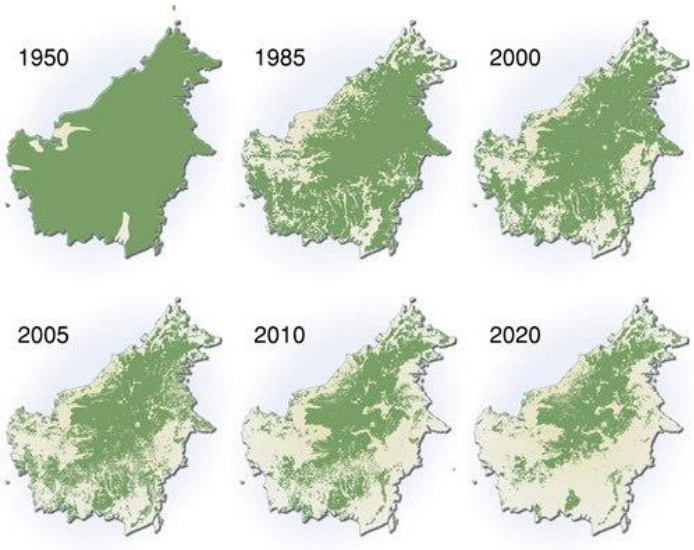
9. Use your model to predict the palm oil production this year if this trend continues. Show how you found your prediction.
   $y=174*1.117^{(2018-1965)}$
   61,286.867 thousand metric tons

10. Use your model to predict the year in which palm oil production will reach 100,000 thousands of metric tons, if the trend continues. Show how you arrived at your answer.
    $100{,}000 = 174*1.117^{(x-1965)}$
    $100{,}000/174 = 1.117^{(x-1965)}$
    $\log(100{,}000/174) = \log(1.117^{(x-1965)})$
    $\log(100{,}000/174) = (x-1965)\log(1.117)$
    $\log(100{,}000/174) = x*\log(1.117) - 1965*\log(1.117)$
    $\log(100{,}000/174) + 1965*\log(1.117) = x*\log(1.117)$
    $x = \frac{\log(100{,}000/174) + 1965*\log(1.117)}{log(1.117)}$
    $x \approx 2022.425$
    by year 2023

Reflecting on the Model

11. What does it mean for the environment and global warming if the demand (and production) for palm oil continues to grow at the same rate? Explain your thinking.
    If production continues to grow, then more rainforest will be cleared to make room for palm oil plantations. Deforestation releases CO_2 into the atmosphere, increasing global temperatures.

The following pictures show the amount of rain forest on Borneo for various years.



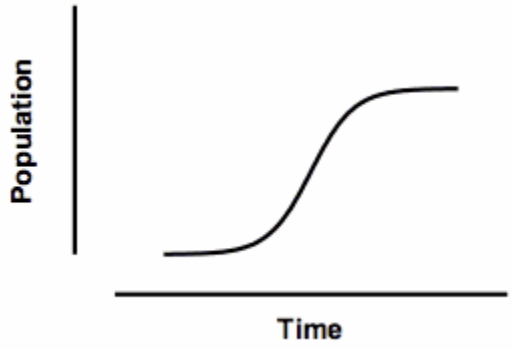
Ahlenius, Hugo. "Extent of deforestation in Borneo 1950-2005, and projection towards 2020." *Last Stand of the Orangutan, Rapid Response Assessment*. GRID-Adrenal, 2007. http://www.grida.no/search?query=extent+of+deforestation+in+borneo+1950+2005+and+projection+towards+2020. 26 May 2018.

12. If palm oil production continues to grow at an exponential rate, what will happen to the rain forest?
    Continue to decrease until no more rainforest in Borneo

13. Use your answer to #12 to explain why an exponential model for the production of palm oil on Borneo will not produce an accurate model in the future.
    This model assumes the rainforest is never-ending, and production can continue to grow forever. However, the rainforests are limited in their area, and therefore there is only so much land that can be converted into palm oil plantations. The growth of the palm oil industry in Borneo will be limited by the total land area.

Second Model: Logistic

If you have data which grows approximately exponentially at the beginning but then the rate of growth slows and eventually approaches a horizontal asymptote (see the curve below), a logistic function may be the appropriate model.



Note: This is typical of mathematical modeling; one model is replaced by a second, more complicated model, which provides a better match to the available data.

A logistic function has the general form: $y = \frac{L}{(1+be^{kt})}$

where *L* is the carrying capacity, the maximum possible output value, and *b* and *k* are constants determined by the data being modeled.

Building the Model

In order to find a logistic equation model for our palm oil production data, we must first estimate the maximum palm oil production possible for the island of Borneo. As often happens in modeling, we will make an assumption in order to get a reasonable estimate of the maximum palm oil production. We will assume the percent of former rainforest used for palm oil production remains constant over time. In 2005 only 50.4% of the rainforest remained (so 49.6% of the former rainforest had be deforested).

1. Use a proportion, and our data on palm oil production from the table on the first page, to estimate the palm oil production if 100% of the rainforest has been deforested for agricultural purposes. This will be our carrying capacity *L*. Show the proportion you used.

   $\frac{\text{amount produced}}{\%\ deforested}$ $\frac{15000}{49.6} = \frac{L}{100}$ $L \approx 30{,}241.935$

2. Replace the *L* in the general form of the logistic function with the value you found above. Also, replace the *t* in the exponent by the translation we used in the data table to convert the years to years since 1965. We can find one of the remaining parameters in this equation by replacing *x* with 1965 and *y* with the palm oil produced that year and solving the resulting equation for the parameter *b*. Find the value of *b* for our logistic model. Show all work.

   General: $y = \frac{30241.935}{1+be^{k(x-1965)}}$

   $y = \frac{30241.935}{1+be^{k(x-1965)}}$ where x = 1965 and y = 174

   $$174 = \frac{30241.935}{1 + be^{k(1965-1965)}}$$

   $$174 = \frac{30241.935}{1 + be^{k*0}}$$

$$174 = \frac{30241.935}{1 + be^0}$$
$$174 = \frac{30241.935}{1 + b(1)}$$
$$174(1 + b) = 30241.935$$
$$174 + 174b = 30241.935$$
$$174b = 30241.935 - 174$$
$$b = \frac{30241.935 - 174}{174}$$
$$b \approx 172.804$$

3. Replace *b* in the general form of the logistic function. Use another (*x*, *y*) pair from the table to replace *x* and *y* in the new formula. Solve the resulting equation for the parameter *k*.

   $y = \frac{30241.935}{1+172.804 \cdot e^{k(x-1965)}}$ answers will vary based on the (*x*, *y*) pair used

   for 1970 k ≈ -0.071
   for 1975 k ≈ -0.092
   for 1980 k ≈ -0.099
   for 1985 k ≈ -0.102
   for 1990 k ≈ -0.112
   for 1995 k ≈ -0.117
   for 2000 k ≈ -0.119
   for 2005 k ≈ -0.128

4. Write the equation for our logistic model for palm oil production in Indonesian Borneo since 1965.

$$y = \frac{30241.935}{1 + 172.804 \cdot e^{-0.128(x-1965)}}$$

answers will vary

Predicting with the Model

5. Use your model to predict the palm oil production this year if this trend continues. Show how you found your prediction.

$$y = \frac{30241.935}{1 + 172.804 \cdot e^{k(x-1965)}}$$

if k = -0.071 $y = \frac{30241.935}{1+172.804 \cdot e^{-0.071(2018-1965)}}$ y ≈ 6034.54 thousand metric tons

if k = -0.128 $y = \frac{30241.935}{1+172.804 \cdot e^{-0.128(2018-1965)}}$ y ≈ 25,295 thousand metric tons

6. Use your model to predict when the palm oil production will reach 30,000 thousands of metric tons.

if k = -0.071 $30000 = \frac{30241.935}{1+172.804 \cdot e^{-0.071(x-1965)}}$ x ≈ 2105.46 by 2106

if k = -0.128 $30000 = \frac{30241.935}{1+172.804 \cdot e^{-0.128(x-1965)}}$ x ≈ 2042.91 by 2043

Reflecting on the Model

7. Describe the assumptions the logistic model is built upon.
   Only for the island of Borneo; exponential growth of palm oil production; production rates continue at same rate; limited only by the amount of rainforest; k is approximated for year chosen

8. Describe, in your own words, what the model shows in the context of the problem. What does the model tell us about the demand (and production) of palm oil if current trends continue? What does the carrying capacity mean in terms of the environmental impacts of such production?
   Palm oil production will continue to grow exponentially until all the rainforests are cut down and converted into palm oil plantations, at which point the production rate will become constant

9. Is the final model you created perfect? How so or why not? Provide evidence to support your conclusion.
   No, other factors impact the model; this model only accounts for production rates and land available if the rainforests are cut down; could be refined (the mathematical modeling process is cyclical)

10. If you wanted to further refine the model, what extra information might you include? How would you incorporate this information into the model? How would the extra information change the final model you created above?
    Palm oil production was for all of Indonesia, would be better to use all rainforests in Indonesia; maybe more land available that isn't covered by rainforest now; but land area limited by other factors such as area needed for living, usable farming land, etc.; after some years the soil might become less usable causing the production rates to decrease instead of staying constant

Discussion Questions

Answer the following questions. Write your answers in complete sentences and provide citations for any research you include.

Answers will vary. Students should include citations of sources used. Answers should be complete and coherent.

Palm Oil: The Negatives

Discuss the negative impacts of palm oil production. One possible resource is Key Sustainability Issues in the Palm Oil Sector

1. Consider the growth of palm oil usage, the human population, and the in-context meaning of the carrying capacity used in your logistic model. The model you created shows a carrying capacity, and therefore a leveling off of palm oil production.
    a. From a global perspective, what do you predict current and future palm oil productions trends will look like?
    Population is growing therefore need for palm oil will continue to grow
    b. Are there other areas of the world suited for palm oil plantations?
    Asia, Africa, North and South America
    c. What impact does the interaction between the palm-oil industry and rainforests on Borneo have on other rainforests worldwide?
    Other rainforests will be converted into palm oil plantations
2. What are some of the direct and subsequent environmental outcomes resulting from deforestation for palm oil production?
    Erosion; habitat loss; loss of species; CO_2 release; global warming > ice caps melting > rising sea levels
3. What are some of the other impacts of producing palm oil, besides environmental consequences?
    Corporate ownership of land; human rights violations

Palm Oil: Only Bad?

4. Benefits of palm oil
    a. What are some of the benefits of palm oil? State the information you find and cite the sources you use.
    b. Research some of the benefits listed on this website: What is Palm Oil? List some of the information you find.
    Economic growth; used in a variety of products; nutritious; the "Tree of Life"
    c. Then check out the page About MPOC on the same website. State what you learn from this "About" page.
    Corporation whose main goals are focused around economic gains
    d. Which information do you trust more, the research you first found, or the information on the MPOC website. Why?
    Information from part a, because the other is funded by a company profiting from palm oil production

Palm Oil: Economic Impacts

According to Gallup, the median annual per-capita income in the USA is $15,480. The median annual per-capita income in Indonesia is $541 (Gallup 2018).
Also, "Indonesia's steady GDP growth since the Asian financial crisis of the late 1990s has earned it widespread consideration among the next group of rising economic powers" (Crabtree 2013).

5. Indonesia is a very poor country and its inhabitants need the money they make from palm oil. The cost of living on Borneo is higher, while the income is slightly lower on Indonesian Borneo. Consider palm oil production and

the economic growth in Indonesia from the point of view of a palm oil farmer. Write a short reflection from a palm oil farmer's viewpoint.

Consider the following information:

"In the past two decades, the gap between the richest and the rest in Indonesia has grown faster than in any other country in South-East Asia. The four richest men in Indonesia now have more wealth than the poorest 100 million people" (Gibson 1).

"Low wages and insecure work for those at the bottom further compounds inequality and prevents workers from lifting themselves out of poverty. Unequal access between rural and urban areas to infrastructure such as electricity and good quality roads compounds spatial inequalities. A concentration of land ownership in the hands of big corporations and wealthy individuals means that the benefits of land ownership accrue to those at the top, at the expense of the rest of society" (Gibson 2).

"Lack of access to land is another factor contributing to inequality. On average, a smallholder farmer in Indonesia controls less than a quarter of a hectare of land, which does not produce sufficient crops to sustain their family. 105 In contrast, according to research conducted in 2015 by Indonesian NGO Transformasi untuk Keadilan (TuK) and economic research consultancy Profundo, 106 just 25 large business groups control 51 percent of the country's 5.1m hectares of oil palm plantations; an area equivalent to almost half the size of Java. Five 57% of the rural road network is in poor condition Just 25 large business groups control 51 percent of the country's 5.1m hectares of oil palm plantations 19 companies have holdings exceeding 300,000 hectares each. A concentration of land ownership in the hands of big corporations and wealthy individuals means that the benefits of land ownership accrue to those at the top and are not shared equally. Unequal access to land drives wider inequality" (Gibson 18-19).

Gibson, Luke. "Towards a More Equal Indonesia." Oxfam Briefing Paper, Oxfam GB for Oxfam International February 2017, Oxford, UK (1-19). https://www.oxfam.org/sites/www.oxfam.org/files/bp-towards-more-equal-indonesia-230217-en_0.pdf

6. How might the view of an average palm oil farmer differ from someone within the Indonesian government?
   Government might be more interested in raising GDP; farmer might not see as many benefits/gains as the government does; farmer might not enjoy the same percentage of the profits

Palm Oil: Personal Contribution

Research some of your favorite products. Try this website: Which Everyday Products Contain Palm Oil?
Then, find a few products you use everyday that include palm oil. Try this website: US FDA Food Additives & Ingredients Database

7. What did you learn about everyday products? Provide examples from the websites above.
8. How much do you contribute to the growing demand of palm oil?
   c. What changes to your personal life can you make?
   d. How likely are you to make such changes?

Palm Oil: Global Initiatives

9. What organizations are working on the palm oil production problem?
   a. What steps are these organizations currently taking to reduce the demand and production of palm oil?
   b. What are some other things *you* can do to help reduce the local/national/global demand for or production of palm oil?
   c. How can you convince others to also make changes?

Reflection

10. Should we try to reduce the demand for palm oil? Justify your answer in your response using your model and the information you considered above.
11. Why is this topic important to you or why should it be important to you?
12. After completing this activity has your view of this topic changed? How so, or why not?