LESSON 14: How can we design a palm farm to support both farmers and orangutans?

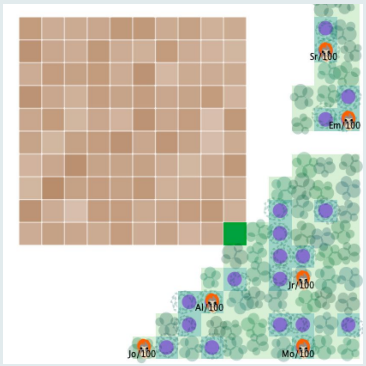
PREVIOUS LESSON

We co-constructed different explanations to the unit driving question and did a gallery walk to view other groups' explanations. We engaged in a Consensus Discussion to decide how changes to ecosystems impact other populations in the system. We used a generalized model to make predictions about different kinds of changes to ecosystems. We demonstrated our learning on an assessment.

THIS LESSON

INVESTIGATION, PUTTING PIECES TOGETHER

5 days



In this lesson, we revise our criteria and constraints for the palm farm design. We investigate crop options and select crops to diversify the palm farm and also financially support farmers. We then investigate how to best utilize a 20% forest corridor with surrounding farms to maximize a local orangutan population. We present our best designs to each other and discuss the features that make each design more or less successful. We write an individual explanation to support our palm farm design. We close out the DQB and celebrate our learning in the unit.

NEXT LESSON

We will take on a local project to investigate, design and/or communicate about a land use change in our area that has led to a decrease in plant biodiversity and how that has affected other living things. We will identify solutions to the problem and implement changes and/or advocate for changes to better support biodiversity and improve the system's resilience.

BUILDING TOWARD NGSS

MS-LS2-1, MS-LS2-2, MS-LS2-4, MS-LS2-5

WHAT STUDENTS WILL DO

Use digital tools and mathematical concepts to compare proposed diversified palm farm designs to provide stable income for farmers based on growing and harvesting rates of crops.

Undertake a design project to construct a diversified palm farm system that improves biodiversity and resilience, which benefits both farmers and orangutans.

Construct an explanation using a diversified palm farm as an example of a system that supports biodiversity and minimizes the risk of disruptions impacting populations.

WHAT STUDENTS WILL FIGURE OUT

- Planting multiple crops on a set area of land, at different ratios, maximizes a farmer's economic yield.
- Planting multiple crops allows for farmers to grow and harvest different crops each year.
- Farmers can reasonably set aside a portion of their land for native ecosystem and not reduce their yield.
- Neighboring farms can coordinate where they set aside native ecosystem to increase corridors for wildlife.
- More forest corridors connecting intact areas of forest increase orangutan populations.

Lesson 14 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**NAVIGATION** Use the Diversified Farm Model to generate a list of features we need to include in our designs.	A	Diversified Farm Model (from Lesson 13)
2	20 min	**REVIEW THE DESIGN CHALLENGE** Revise the design goal, criteria, and constraints to more specifically define the design task.	B-C	*Palm Farm Design Task*, original *Palm Farm Designs* (from Lesson 5), chart paper, markers
3	20 min	**MEET AND SELECT CROPS** Have students read about five crop choices and develop a Gantt chart to ensure they have a crop to sell every year.	D	*Palm Farm Design Task*, colored pencils, *Popular Crop Choices in Indonesia*
				End of day 1
4	5 min	**NAVIGATION** Have students take stock of the crop selection process and brainstorm information they need to evaluate as to whether their choices will lead to a stable income.	E	
5	15 min	**INTRODUCE THE CROP CALCULATOR TOOL** Model the Crop Calculator Tool using 3-4 students' designs.		*Money Per Crop Calculation Sheet* (optional), computer and projector, Crop Calculator Tool
6	15 min	**CHECK DESIGNS WITH CROP CALCULATOR TOOL** Have students work with partners to test their design ideas in the calculator tool, adjusting ratios to stabilize income.	F	*Palm Farm Design Task*, Crop Calculator Tool
7	10 min	**BUILDING UNDERSTANDING DISCUSSION ABOUT DESIGNS TO SUPPORT FARMERS** Facilitate a whole-group discussion reflecting on progress toward meeting criteria to support farmers.	G	*Palm Farm Design Task*, computer and projector, Crop Calculator Tool
				End of day 2
8	8 min	**NAVIGATION** Have students complete Part 5 of their design handout and/or share their written explanation with a partner.	H	*Palm Farm Design Task*
9	7 min	**FOCUS ON UTILIZING 20% OF FOREST TO SUPPORT ORANGUTANS** Have students brainstorm ways that they can better utilize the 20% of forest they have set aside to support orangutans.	I	chart paper, markers
10	18 min	**DEMONSTRATE THE PALM FARM MODEL** Demonstrate for students how to use the computer simulation to test different locations of the 20% of forest to see how it affects orangutan populations.		computer and projector, Palm Farm Design: 1-Farm Orientation video, Palm Farm Design: 4-Farm Orientation video, Palm Farm Design simulation
11	12 min	**SMALL-GROUP BRAINSTORM OF DIFFERENT DESIGNS TO TEST** Arrange students into groups of 4 to brainstorm designs for using the 20% of forest strategically among 4 nearby farms.	J	*Palm Farm Design Task*, colored pencils
				End of day 3

Part	Duration	Summary	Slide	Materials
12	20 min	**SMALL-GROUP TESTS** Have students meet in their groups to run tests on their different designs and record the best design to support orangutans.	K	*Palm Farm Design Task*, computer or device, Palm Farm Design simulation
13	10 min	**CONSENSUS DISCUSSION ABOUT BEST APPROACHES**	L	*Palm Farm Design Task*, computer and projector, Palm Farm Design simulation
14	12 min	**CONSTRUCT AN EXPLANATION TO SUPPORT A PALM FARM DESIGN** Write an individual explanation describing the best palm farm design and how it supports both farmers and orangutans.	M	*Palm Farm Design Task*
15	3 min	**NAVIGATION AND HOME LEARNING** Assign students home learning to review and annotate the questions for the Driving Question Board, which they will revisit in the next class period.	N	*Let's Answer Questions from Our Driving Question Board!*
				End of day 4
16	5 min	**NAVIGATION** Have students share with a partner which questions they have marked from their home learning. Then students place sticky dots on the questions that they think we have made progress on and move into their Scientists Circle.	O	*Let's Answer Questions from Our Driving Question Board!*
17	25 min	**REVISIT OUR DRIVING QUESTION BOARD (DQB)** Students revisit the DQB and take stock of all of the questions we have now answered with the whole class.	P	*Let's Answer Questions from Our Driving Question Board!*, Driving Question Board, 3 colors of sticky dots
18	15 min	**QUICK WRITE: REFLECT ON OUR EXPERIENCES** Students discuss what was challenging and rewarding about this unit and complete a quick write about their learning experience.	Q	
				End of day 5

Lesson 14 • Materials List

	per student	per group	per class
Lesson materials	• science notebook • *Palm Farm Design Task* • original *Palm Farm Designs* (from Lesson 5) • colored pencils • *Popular Crop Choices in Indonesia* • *Let's Answer Questions from Our Driving Question Board!*	• *Money Per Crop Calculation Sheet* (optional) • Crop Calculator Tool • computer or device • Palm Farm Design simulation	• Diversified Farm Model (from Lesson 13) • chart paper • markers • computer and projector • Crop Calculator Tool • Palm Farm Design: 1-Farm Orientation video • Palm Farm Design: 4-Farm Orientation video • Palm Farm Design simulation • Driving Question Board • 3 colors of sticky dots

Materials preparation (minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Prior to day 1: Print 1 copy of *Palm Farm Design Task* for each student, single-sided if attaching to science notebooks and double-sided if not attaching to science notebooks.

Prior to day 2: Download or access via Google Sheet the Crop Calculator Tool from https://www.teachersopensciedfieldtest.org/palmoil . Spend time orienting yourself to this spreadsheet calculator. Play with the ratios for each crop in column D. The more you explore the tool prior to day 2, the more comfortable you will be using it with your students. Decide how to organize students' use of this tool on day 2 and how to best allow students to access it. Examples include: (1) preloading the tool on students' devices, (2) loading the spreadsheet on the class's shared drive that students can access, and (3) loading the spreadsheet onto your class website for students to download and open on their devices.

Prior to day 3: Make sure you can open the Palm Farm Design simulation from https://www.teachersopensciedfieldtest.org/palmoil and project it on a screen that is large enough for everyone to see it. Alternatively, you can download the sim code file and run it directly from your computer. Instructions for different methods to access the Netlogo simulations are located at the field-test website: https://www.teachersopensciedfieldtest.org/palmoil. Watch all the Orientation and Advance Prep videos located on the field test website ahead of time. You can show the two orientation videos to your students, but the advance prep video is developed for teacher use only.

Prior to day 4: Before day 4, type up or take a high resolution photograph of all of the questions on the DQB and modify the handout, *Let's Answer Questions from Our Driving Question Board!*, with these questions. If you take a photograph, insert the photograph in place of the table on a handout. If using the table format, add as many rows as needed to the table.

Prior to day 5: Display important classroom consensus models around the room. Make sure the Driving Question Board is displayed.

Lesson 14 • Where We Are Going and NOT Going

In the previous lessons students have learned that systems with a larger variety of plant types support biodiversity and create more resilient systems to handle disruptions. Diversified farms are one type of these systems. This lesson is students' opportunity to apply what they have learned throughout the unit to design a diversified farm system that supports orangutans and farmers.

Students are adding one new idea about wildlife corridors that was alluded to in Lesson 11 with prairie strips. A new key takeaway from this lesson is the idea that individual farmers can amplify their impacts by coordinating with neighboring farms to utilize forest setbacks to the benefit of wildlife.

Students should demonstrate their use of several important science ideas as they engage in this design task:

- Diversified systems are resilient to disruptions.
- Diversified farm systems can support farmers by reducing their financial risk in a disruption event.
- Diversified systems can support biodiversity.
- Farms can set aside a portion of their land and still maintain productivity levels.

This lesson builds on 3rd and 5th grade DCIs: "Populations live in a variety of habitats, and change in those habitats affects the organisms living there" (grade 3) and "A healthy ecosystem is one in which multiple species of different types are each able to meet their needs in a relatively stable web of life" (grade 5). Students extend their understanding to realize that human-managed systems, like farms, are ecosystems, and these ecosystems can be designed to better support organisms that lived in the ecosystem before the farm was developed.

LEARNING PLAN for LESSON 14

1 · NAVIGATION

5 min

MATERIALS: Diversified Farm Model (from Lesson 13)

Brainstorm a list of features for a diversified palm farm. Display **slide A** and have your class's Diversified Farm Model from Lesson 13 located where students can view it. Have students turn and talk first about the question prompt on the slide:

- Based on our model, what features do we need to include in a design for a better palm farm?

After 2 minutes, bring the students back together in a whole-group discussion. Ask students to share one thing they discussed in partners. Elicit ideas from at least 4-5 partners.

Suggested prompt	Sample student responses
Based on our model, what features do we need to include in a design for a better palm farm?	*Many different crops.* *At least some crops that are resistant to disease.* *At least some crops that always bring in money.* *Some crops that support animals, insects, and birds.* *A farm with native habitat, like prairie strips or designed kind of like the forest.* *A farm with different "stories," so taller and shorter plants.*

Say, *Wow, we've learned a lot about different ways we can farm to support wildlife and to support animal populations. Now it's our opportunity to put some of these ideas into a real design to see if we can offer a way to farm oil palm but also protect the orangutans. We'll get to test our ideas in a simulation based on real data to see how well our designs actually work.*

2 · REVIEW THE DESIGN CHALLENGE

20 min

MATERIALS: science notebook, *Palm Farm Design Task*, original *Palm Farm Designs* (from Lesson 5), chart paper, markers

Articulate the palm farm design task. Pass out 1 copy of *Palm Farm Design Task*. This is a packet that will be used across the course of the entire design task. It will be used every day of this lesson and should be attached to students' notebooks now or at a future point in the lesson.

Read through the problem together. Ask students if there are any additions or edits to make. Then display **slide B**. Mention briefly that we are going to shorten the name of our farm to "palm farm" but remind the students that we are talking about oil palm plants.✱

Revise the design goal. Direct students to find *Palm Farm Designs* (from Lesson 5) already attached in their science notebooks. Students should read the original goal. Elicit from students ideas for how they want to revise the original goal now that they know more. Record the revised goal on chart paper for the class (or on the classroom whiteboard) as students record the new goal under Part 1 on their *Palm Farm Design Task* handout.

✱ SUPPORTING STUDENTS IN ENGAGING IN CONSTRUCTING EXPLAINING AND DESIGNING SOLUTIONS

In this moment, students articulate a shared design goal and criteria and constraints they will use in the design task. Keep a class record of the design goal and criteria and constraints that is visible to students and that can be revisited and modified should the class agree to change something as the design task progresses.

Sample change:

Original design goal	Revised design goal
A palm farm that meets a farmer's need for crops to sell and also keeps orangutan and tiger populations steady (or goes up) (from Lesson 5).	A palm farm that meets a farmer's need for crops to sell, minimizes risk of disruption, and supports orangutans and other populations (biodiversity). Or A palm farm that supports biodiversity and is resilient to disruptions to benefit farmers and orangutans.

Review and revise the criteria for the design challenge. Keep **slide B** displayed. Direct students to read the original criteria they recorded in Lesson 5. Elicit from students ideas for how they want to revise the criteria now that they know more.

Revise the criteria about farmers. Facilitate a discussion about this criteria from Lesson 5 (e.g., farmers have the same amount of crop to sell or farmers still make money from their land). The purpose of this discussion is to help students articulate what they have learned about disruptions that affect farmers (disease, drought, market prices) and solutions they learned about to minimize the disruption (diversifying farms).

Suggested prompts	Sample student responses	Follow-up questions
How can we ensure our farm makes us money?	*Has enough crops to sell.* *Has different kinds of crops.*	*How much land did we learn a farmer can use and still be productive?* *Why do different kinds of crops help to support a farmer in making money?*
If we agree that our farms should have several different kinds of plants, how many?	*A lot.* *At least 2 or more.* *The examples we saw had 3 or 4.*	*Should we set a criterion that we all include at least 3 crops? How would that help us meet our design goal? (Answer: minimize risk to farmer.)*
What did we learn about farmers being able to set aside land for native ecosystems?	*We saw that soybean farmers could use 15-20% of their land for prairie strips, and it didn't affect yield.*	*How can we use this to design our farm? Would we want a farm that is financially productive using 80% of the land and saving 20% for orangutans and other animals?*
Are we interested in maximizing profits or having a stable income?	*Stable income, so we always make money each year.*	

Record the revised criteria on chart paper for the class (or on the classroom whiteboard) as students record the new criteria under Part 2 on their *Palm Farm Design Task* handout.

Original criteria for farmers	Revised criteria for farmers
Farmers have the same amount of crop to sell or farmers still make money from their land.	1. Farm with 3 or more crops to sell, 2. steady income from the crops, and 3. using only 80% of land.

ADDITIONAL GUIDANCE

As the class revises the criteria and constraints, use this opportunity to specifically emphasize engineering DCI ETS1.A: Defining and Delimiting Engineering Problems: "The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge likely to limit possible solutions."

Revise the criteria about orangutans and tigers. Facilitate a discussion about this criterion from Lesson 5 (e.g., the amount of orangutans and tigers stay the same or go up). This discussion should help students articulate what they have learned about resource availability and biodiversity supporting orangutan populations.

Suggested prompts	Sample student responses
What did we learn that orangutans need?	*Fruit trees mostly if they want to reproduce.* *Canopy for shelter and protection.*
What could we do to include some canopy and fruit options for them on our farms?	*Tall trees, fruit trees, and the 20% of our land can be rainforest, too.*

Discuss constraints on the computer simulation and whether we need to measure tiger populations. The computer environment to test students' palm farm designs will not include tigers. Share this information with your students. Display **slide C**. Read through the slide together and discuss how orangutans, as a keystone species, could be used to indicate tiger population health, too. Then add a criterion to the list focused on measuring orangutan population size.

Original criteria for orangutans/ecosystem	Revised criteria for orangutan/ecosystems
The amount of orangutans stays the same or goes up. The amount of tigers stays the same or goes up.	4. Stable or increasing orangutan population.

ADDITIONAL GUIDANCE

The purpose of **slide C** is not to teach students about keystone species, but rather to help students understand that, if we monitor the conservation of some populations, we can expect that other populations are doing well. In reality, there are poaching factors related to both orangutans and tigers that we chose not to include in the unit, which complicate the dynamics of whether orangutans can serve as an indicator of tiger population health. For the purposes of the palm design task, it may be necessary to make this assumption to satisfy students' needs to protect both tigers and orangutans.

Discuss constraints to the design task and computer simulation. Share background information about the upcoming tasks that students will complete. Given this information, have students brainstorm constraints that they can expect, which are limitations to their designs. If students struggle to come up with constraints, you may want to suggest one of the following:

- limited selection of Indonesian crops to choose from or
- limited to a certain amount of land.

This should complete Part 2 of students' *Palm Farm Design Task* handout. Make sure students record the agreed-upon criteria and constraints.

3 · MEET AND SELECT CROPS

20 min

MATERIALS: science notebook, *Palm Farm Design Task*, colored pencils, *Popular Crop Choices in Indonesia*

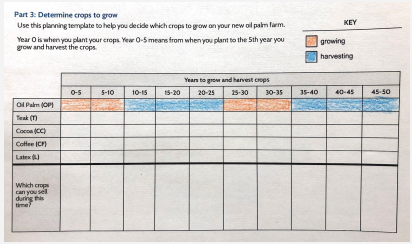
Set the purpose for testing criterion 1. Say, *Let's get to work on criterion 1 to make sure we plant a farm with 3 or more crops and that we have something to harvest each year. We need to make sure we grow the right mix so that we always have something to sell. What are some things we need to consider to help us decide which crop will do this for us?*

Elicit ideas from students. Students may suggest:

- *How long it takes for the crops to grow.*
- *How many times or years you can harvest from the crops.*

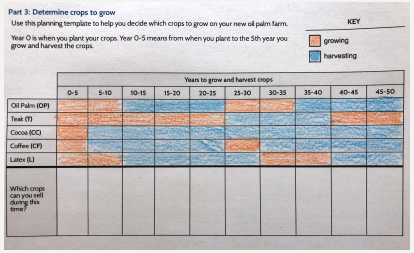
Introduce students to the crops. Display **slide D** and pass out a copy of *Popular Crop Choices in Indonesia* located in the *Student Edition*. Review the information on the sheet about each group, which includes how long it takes to grow the crop and how long you can harvest before needing to replant.

Model how to complete the Gantt chart for oil palm. Since all farms will include oil palm, model how to complete the Gantt chart on Part 3 of students' *Palm Farm Design Task* handout. Students shade in one color for the years during which the crop is growing and use a second color for the years that the crop is ready for harvest. They can color in their key at this time.



Because oil palm takes 10 years to grow, years 0-5 and 5-10 should be colored as "growing". Oil palm can then produce fruits until they are 25 years old, so years 10-15, 15-20, and 20-25 should be colored in as "harvesting".

Give students time to pick their crops from the other 4 options. Students need only 3 crops total with oil palm being one of the crops. They must select at least 2 more crops and can select up to all 5 crops.



Prompt students to read the reference sheet to locate crop information. Once selected, students should color in the growing and harvesting information for each crop on their Gantt chart.

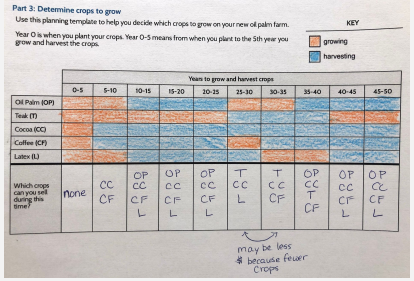
Circulate around as students complete their Gantt charts and assist as needed.

In order to determine if students have designed a farm that can sell a crop each year, they will need to go year by year to determine which of the crops they selected are available for harvesting. In the bottom row of their table, they can write in the abbreviation for each crop that would be harvested during the time period.

Allow students to have at least years 0-5 and/or 5-10 as ones that do not count against them with respect to meeting the criteria. We can agree that all crops need time to grow.

If students find that they have a time period without a crop to harvest, they can revise or add to their crops. The example to the right shows all 5 crops included in a Gantt chart, but students may decide to include as few as 3 crops and still meet the criteria.

If time permits, allow students to share their crop selection Gantt charts with each other.



To close the lesson, celebrate the variety of the different designs you saw as you circulated around the room. Say, *I saw designs with 3, 4, and all 5 crops. In the next class, let's test to see if our choices will help us meet our other criteria for a stable income from the crops we have selected.*

End of day 1

4 · NAVIGATION

5 min

MATERIALS: None

Taking stock of criterion 1 and looking ahead at criteria 2 and 3. Display **slide E**. Use the prompts on the slide to ask students how they are feeling about criterion 1 and to generate new ideas about the next criteria to design for and evaluate. The prompts include:

- How are we feeling about criterion 1?
- Did we find a design that used at least 3 crops *and* also gave us crops to harvest every year?
- How are we going to tell if the crops we chose will make us a stable income?

When you discuss the third question, ask students what we need to know to figure out income from crops. Listen for students to suggest:

- how much the crops are worth,
- how much you can grow on a piece of land, and
- how much you can sell from each crop grown.

5 · INTRODUCE THE CROP CALCULATOR TOOL

15 min

MATERIALS: *Money Per Crop Calculation Sheet* (optional), computer and projector, Crop Calculator Tool

ADDITIONAL GUIDANCE

To develop the Crop Calculator Tool, the design team engaged in a lot of computational thinking. If time permits, you can engage your students in some of this same computational thinking that is built into the tool. This will give your students some insight into how the tool works and a better understanding of what went into making it.

This activity is optional and will require more time. Arrange students into groups of 5 with 1 calculator for each student. Make 1 copy of the *Money Per Crop Calculation Sheet* handout per group. Assign each group member 1 crop to calculate. Choices include oil palm, cocoa, coffee, latex, and teakwood. Have students find the average price per ton for their crop and record these on their handout. Students then multiply the price per ton by the ton per acre factor that is provided to them. This will calculate the price per acre (earning potential) for each crop. Importantly, discuss what each of these pieces of the algorithm relate to in the real world:

- Price per ton reflects the value of the crop on the market (how much we can sell it for given a certain amount).
- Ton per acre reflects the yield (the amount we can get out of an acre of this crop).
- Price per acre is a value that we can use to decide how much land we want to set aside for each crop.

Demonstrate the Crop Calculator Tool with 3 students' designs. Gather students in a Scientists Circle or whole-group format in which they can all see the computer projection. Your goal is to model for students how to use the Crop Calculator Tool before they have the opportunity to do it in partners and small groups.

Open the Crop Calculator Tool from https://www.teachersopensciedfieldtest.org/palmoil . The tool can look overwhelming at first so take a moment to orient students to the tool. Ask students, *Does anything on the spreadsheet look familiar to us?* Listen for students to identify:

- *crops we are choosing from are in the spreadsheet and*
- *there is a "growing" and "harvesting" schedule like we did in the previous class.*

Then ask, *What are some new things we see in the spreadsheet?* Listen for students to identify several new features.

Suggested prompts	Sample student responses	Follow-up questions
What are some new things we see in the spreadsheet?	*There are areas A, B, C, and so on.*	*What do we think "area" refers to when we are talking about a farm?*
	There's % of land.	*What could "percent of land" mean?*
	There's a price per acre.	*What do you notice about the value of each of our crops to choose from?*
	There's a table with number signs.	*What do you think $ per year could mean for each row that has a crop by it?*

Suggested prompts	Sample student responses	Follow-up questions
	There's an empty graph.	*Where else have we used and seen graphs? How can these be useful to us?*

The Crop Calculator Tool should be set to 100% forest and 0% for all crops in column D, which is why the income table shows all zeros. Once you assign a value to each crop in column D, this indicates planting a portion of the land. The income table will respond. Column D will be your primary column for all the tests you run.

Tell students that the Gantt chart shown in this calculator is mostly fixed based on our growing and harvesting schedule.

ADDITIONAL GUIDANCE

The Gantt chart in the Crop Calculator Tool can be a fixed feature in the tool. However, we designed the tool with added flexibility to stagger crop planting and harvesting, should you want to layer on those options for students. You can do this by changing the cells in the Gantt chart from "growing" to "harvesting" to "none."

Teakwood presents one issue of which to be aware. Once harvested, teakwood is no longer a crop we can harvest again. For that reason, we assumed that the teakwood would be harvested from year 26 to year 40, during three time intervals. The total value of the teakwood is $24,000 per acre. Since a third of the crop is harvested at each time interval, we assigned a value of $8,000 to the crop in column C. It is possible to harvest the teakwood in a shorter or longer time period; therefore, if you want to harvest this crop over a different length of time, divide $24,000 by the number of time intervals in which you plan to harvest it. Replace the value of $8,000 in column C with your new value.

Remind students of their criterion to only use 80% of land and reserve 20% for forest. Set the "forest" in column B to "20" in column D. Notice the "total" cell (D:8) will turn red and say "20." This indicates that only 20% of the land has been assigned.

Model the first crop selection. Ask 1 student who selected 3 crops to share their design. Ask the student how much land they want to assign to each of the 3 crops, which needs to total 80%. Set the other 2 crops to zero. Check that the total land, including forest, adds up to 100% (cell D:8). As you assign values to the crops, the income table and histogram will populate. Take a moment to examine the data together. Look at cell O:15 to get an average income per year value. Examine the histogram to see if the income looks stable over time. Ask the student if they want to adjust the percentages. Plug in new numbers to column D and ask the class to remark on any changes they noticed to the average annual income or the histogram.

ADDITIONAL GUIDANCE

As you model the tool, you may want to engage students in thinking about a few additional considerations beyond monetary value. Some crops are higher value (e.g., teakwood) but with trade-offs, such as a long growing time. Other crops may have a low value (e.g., cocoa) but grow quickly, produce for a long time, and grow well in the shade of the taller palm, teakwood, and rubber/latex trees. Unfortunately, we could not include all of the expenses associated with the maintenance of each crop, so the computer model is limited in many ways. The strength of the model is that it allows students to manipulate the system (ratios of land) to see how setting aside different amounts of land for different crops affects income.

Repeat this same process for 1 student with a 4-crop design and 1 student with a 5-crop design. The goal again is to model for students how to set values in column D for each crop to total the land to 100% so that, when they test their own designs in the tool, they better understand with which part of the calculator they are working. As you enter each set of values into column D, point out to students that the only thing they are manipulating in this model is the amount of land assigned to each crop (column D), which is their independent variable. Ask them to identify the dependent variable (income) and control variables (crop price, crop growing/harvesting schedule).

Once you have modeled how to use the tool, take a moment to preview Part 4 of students' *Palm Farm Design Task* handout so that they know what they need to record from the tool. Students are to record their "best" design, or best set of ratios for land to each crop they want to plant. This means that students can play around with changing the ratios in column D until they are satisfied with the income outputs. Remind students that they are aiming for a stable income over time, and that "stable" does not mean "the same" every year. Normal fluctuation is acceptable, but large fluctuations in income could be problematic.

6 · CHECK DESIGNS WITH CROP CALCULATOR TOOL

15 min

MATERIALS: science notebook, *Palm Farm Design Task*, Crop Calculator Tool

Assign students to partners to test their designs together. Display **slide F** as a reminder to students as they work. Have students access the Crop Calculator Tool, which has been previously loaded to their devices or placed on the classroom Google drive or website. After opening the tool, give the first partner 5 minutes to test different scenarios, with the other student assisting and serving as a thought partner. After 5 minutes, remind students to record their best set of ratios for income under Part 4 on their handout and then switch to test the other partner's design.

Note that you can make this calculator available to students to work with at home via a class website or drive. This would allow students to consider additional adjustments to their crop choices and ratios, until they are completely satisfied with their design.

7 · BUILDING UNDERSTANDING DISCUSSION ABOUT DESIGNS TO SUPPORT FARMERS

10 min

MATERIALS: science notebook, *Palm Farm Design Task*, computer and projector, Crop Calculator Tool

Facilitate a Building Understandings Discussion on how their current designs support farmers. Bring students back together for a whole-group discussion. Display **slide G** but also have the Crop Calculator Tool readily accessible to check ideas as students share them.

KEY IDEAS

Purpose of the discussion: to evaluate how well our designs are supporting farmers and meeting our design goals for a resilient farm that supports biodiversity.

Listen for student ideas:

- It was hard to get the income stable every year.
- Some crops bring in a lot of money but do not provide stable income.
- Other crops bring in a steady income but aren't profitable.
- The mixed crops have different heights to them more like a forest, so even if some crops aren't worth as much, it could be helpful to plant them for animals.
- The mixed crops are better for farmers if there is a disease or a change to the market price for one crop.

Suggested prompts	Sample student responses
What seemed to improve or lower income?	*Selecting the high value crops, like oil palm and coffee and teakwood. This gave us a higher total income but was not always stable.*
What seemed to help income become more stable over time?	*Choosing consistent crops, like cocoa, that bring money each year, but this lowered overall income.*

Suggested prompts	Sample student responses
How do we feel about meeting our first 3 criteria for our palm farm designs?	*We can make money with 3 or more crops.* *We can make steady income if we plant the right ratio. There's some up and down, but we can make sure we always have money.* *We can do this with only 80% of the land.*
Do we feel our diversified farms have potential to be resilient? To support biodiversity (our goals)?	*Our farms will work better, if there is a disease that affects only 1 plant, because the other plants can keep growing and bringing us income.* *Our farms will work better to support wildlife because there are tall trees and shorter bushes underneath, more like a forest.*

Getting a stable income is a challenge, so take time to discuss how farmers might handle one time period during which they make a lot of money and another time period during which their income goes down. This is a good opportunity to talk about how farmers stagger their planting to help stabilize their income (and workload).

There are two options for ending day 2 based on your timing and whether you plan to assign home learning:

- Assign Part 5 of the design handout (i.e., the explanation) for home learning. Use the navigation at the start of next class for students to share their explanation with a partner.
- Preview that, in the next class, they will complete Part 5 of their design handout. Then they will start looking at whether their farms can support orangutans with the 20% of forest they have set aside.

End of day 2

8 · NAVIGATION

8 min

MATERIALS: science notebook, *Palm Farm Design Task*

Write and/or share a written explanation for how the design supports farmers. Display **slide H** (modify as needed) and direct students to Part 5 on their *Palm Farm Design Task* handout. If previously completed for home learning, assign students to partners to share and get feedback on their written explanations. If not yet completed as home learning, give students time to review Parts 3 and 4, and to write an explanation on Part 5.

9 · FOCUS ON UTILIZING 20% OF FOREST TO SUPPORT ORANGUTANS

7 min

MATERIALS: chart paper, markers

Generate a list of ideas for how to use the 20% of forest we set aside. Gather students in a Scientists Circle. Display **slide I** and facilitate a class brainstorm focused on how to maximize a local orangutan population with 20% of forest from our farms. Record student ideas on chart paper.

Suggested prompts	Sample student responses
What factors do we need to think about to help us decide where and how to use the 20% of forest we set aside?	*What type of land is around our farm.* *Whether there is forest nearby.* *Whether some of the land we own has important plants already growing on it, like fruit/fig trees.* *Where there is a creek or water on the land.*
How will our choice about where to put the forest help or not help orangutans?	*It will help orangutans if it's near other forest or near fruit trees that they need.* *It will help orangutans if it's near water so that they have water to drink.* *It will not help orangutans if it's far away from the forest, like the opposite side of the farm, because they can get to it without going on the ground.*

Say, *We have a computer simulation in which we can change where we put the 20% of forest on our farm and see what happens to the local orangutan population. How do you think this kind of simulation could be useful to our palm farm designs?*

Listen for students to suggest:

- We could see if having it next to forest helps.
- We could see if having it opposite of the forest is worse.
- Would could see if having it all together in one area is better than if we break it apart.

10 · DEMONSTRATE THE PALM FARM MODEL

18 min

MATERIALS: computer and projector, Palm Farm Design: 1-Farm Orientation video, Palm Farm Design: 4-Farm Orientation video, Palm Farm Design simulation

ADDITIONAL GUIDANCE

At the time of printing this teacher guide, the simulation was still undergoing final development. Please visit https://www.teachersopensciedfieldtest.org/palmoil for a link to the NetLogo simulation and for guidance on how to model for your students the new simulation features, and how to scaffold students' work as they test different designs. On the field test website you will also find two orientation videos that you can show your students, as well as a video specifically made for you, called *Palm Farm Design Simulation: Advance Prep.* This video will help you understand the features and capabilities of the simulation so you can better support your students.

Demonstrate the Palm Farm Design simulation. Have your students gather in a Scientists Circle. Project the *Palm Farm Design: 1-Farm Orientation video* from https://www.teachersopensciedfieldtest.org/palmoil . After the video, review some of the features of the new simulation with your students. Have students share what they noticed about the new simulation and how they think this simulation will allow them to test their second design criteria focused on supporting a healthy orangutan population.

Run a baseline trial on the orangutan populations with farmers using 100% of forest. Open the *Palm Farm Design* simulation using the link found at https://www.teachersopensciedfieldtest.org/palmoil . Set up a test so that the farms use 100% of their land. Run up to 5 trials. As you run the trials, have students share what they observed about the orangutan population over time. Ask students if they

would consider this a stable population. Also, model for students how to adjust the simulation to run multiple trials is less time.

Add the 20% of forest to one farm and run trials. Decide on one farm with which to work first. Allow students to help you choose where to put the 20% of forest in patches, corridors, and/or adjacent to other features in the simulation. Run up to 5 trials on each design to see how the orangutans respond. With each design, discuss the pattern in the data, focusing on:

- 20% of forest doesn't help you get better results unless its strategically placed in certain configuration that will help orangutans access new food resources.

Facilitate a class discussion throughout this demonstration asking students (1) what they notice about each design and (2) why they think the design led to the results in orangutan population.

Transition to the 4-farm design model. Say, *We've only been testing this one farm, but now we're going to think bigger. What if we were to coordinate with each other to be strategic about where we place our 20% of forest? How could this benefit orangutans?* Listen for students to suggest:

- We could make larger areas of forest by combining ours together.
- We could make "trails" or bridges across farms to connect the forests together.

Then show *Palm Farm Design: 4-Farm Orientation* video from https://www.teachersopensciedfieldtest.org/palmoil . Prepare students for small group work on Part 6 and Part 7 on their design handout.

ADDITIONAL GUIDANCE

At this moment, introduce students to the concept of a "wildlife corridor". Say, *I've heard that land we set aside for wildlife are called corridors. Where have you heard that word "corridor" before?* Take a brief moment to let students share ideas and even add the word to your word wall.

11 · SMALL-GROUP BRAINSTORM OF DIFFERENT DESIGNS TO TEST

12 min

MATERIALS: science notebook, *Palm Farm Design Task*, colored pencils

Plan in small groups for strategic use of forest set asides. Arrange students in groups to design different ways to test the 4-palm-farm model. Display **slide J**, which includes instructions to help students plan. Direct students to Part 6 on the *Palm Farm Design Task* handout. This section of the handout includes 2 diagrams from the simulation that do not include the 20% of forest. Students will use a colored pencil to shade in roughly 20% of each farm in ways they believe will benefit orangutans. They can work with their group to generate up to 2 different designs that they want to test in the simulation.Students should be prepared to run these designs in the next class.

End of day 3

12 · SMALL-GROUP TESTS

20 min

MATERIALS: science notebook, *Palm Farm Design Task*, computer or device, Palm Farm Design simulation

Test different designs in small groups. Display **slide K** with instructions. Have students use their plans on Part 6 to guide how they set up each scenario. They should run at least 5 trials and record their results in Part 7 of their handout. Remind students to speed up the model in order to run trials more quickly.

Groups can spend approximately 2 minute setting up their design and then up to 7 minutes running trials to test how the design impacts the orangutan population. After about 9-10 minutes, they should move to their second design.

After 20 minutes, students will need to end their tests. They may not have finished testing all of their ideas, but they should have gathered enough data to identify ways to use the 20% of forest that worked or did not work.

13 · CONSENSUS DISCUSSION ABOUT BEST APPROACHES

10 min

MATERIALS: science notebook, *Palm Farm Design Task*, computer and projector, Palm Farm Design simulation

Facilitate a Consensus Discussion about what features led to stable orangutan populations. Display **slide L.** Remind students to use evidence, recorded in Parts 6 and 7 of their handout, to support their ideas during the discussion. Have the Palm Farm Design simulation ready to view if needed during the discussion.

KEY IDEAS

Purpose of the discussion: to agree that strategic placement of forest corridors can lead to stable orangutan populations, particularly when the 20% of forest is used to bridge between existing forest or combined in ways to make a larger forest for orangutans, especially when it expands access to food resources.

Listen for student ideas:

- Use of forest that expanded orangutans' access to resources (space, food) helped.
- Use of forest that did not expand access a great deal did not seem to help.

Suggested prompts	Sample student responses
What designs seemed to decrease or not help the orangutan population?	*Placing the forest corridor near a small forest with few orangutans.*
What designs seemed to increase or help the orangutan population?	*Placing the forest corridor near a large forest with more orangutans.* *Using the forest corridor to connect other forests together.*
Why did these designs work better?	*The orangutans had access to more land and food and forest and could get food from more places.* *If the orangutan was trapped in one spot, it eventually died, but letting it connect to other areas, kept it alive so that it could reproduce.*

14 · CONSTRUCT AN EXPLANATION TO SUPPORT A PALM FARM DESIGN

12 min

MATERIALS: science notebook, *Palm Farm Design Task*

Construct an explanation to support a palm farm design. Have students return to their seats. Display **slide M**. Direct students to Part 8 of their *Palm Farm Design Task* handout. Read through the explanation prompt together. Then give students at least 10 minutes to develop an individual explanation supporting their ideas for a better designed palm farm that works for farmers and orangutans.

ASSESSMENT OPPORTUNITY

Students should identify 2 features of a diversified palm farm that support farmers and biodiversity and how each of these features works. Example features include:

Feature	How it works
Many crops	Protects farmers in case of a disruption and can give them steady income. Creates multiple layers, which act more like a forest for animals, insects, and birds.
Forest set aside or corridor	Farmers can get the same amount of crop with less land. Protecting part of the land for forest creates corridors for animals to travel through.

Students should explain that together these features create a system that better supports a farmer because it minimizes the farmer's risk in case of a disruption. These features better support biodiversity by having more types of plants in the farm area, which support more kinds of consumers. The corridors combined with more diverse crops provide animals with more space and habitat in which to live.

15 · NAVIGATION AND HOME LEARNING

3 min

MATERIALS: science notebook, *Let's Answer Questions from Our Driving Question Board!*

Say, *We've figured out so much! I bet we can answer many of our questions on the Driving Question Board.*

Assign reviewing the DQB questions for home learning. Present **slide N**. Tell students that they will revisit their Driving Question Board and celebrate all that they have figured out in the next class. Hand out a copy of *Let's Answer Questions from Our Driving Question Board!*, which you created to contain all of the student questions from the DQB, and have students tape it into their science notebooks.

Have students evaluate which questions the class has answered from the DQB for home learning. Have students mark questions that they think the class has answered by putting different symbols next to each question:

- We did not answer this question or any parts of it yet: **?**
- Our class answered some parts of this question, or I think I could answer some parts of this question: ✓
- Our class answered this question, or using the ideas we have developed, I could now answer this question: ✓✓

End of day 4

16 · NAVIGATION

5 min

MATERIALS: science notebook, *Let's Answer Questions from Our Driving Question Board!*

Have students work in pairs to evaluate which questions the class has answered from the DQB.✱ Project **slide O**. Ask students to take out their home learning, *Let's Answer Questions from Our Driving Question Board!*, which you created to contain all of the student questions from the DQB, and have students tape it into their science notebooks. Have students work with a shoulder partner to compare which questions they marked to indicate what they think the class has answered:

- We did not answer this question or any parts of it yet: **?**
- Our class answered some parts of this question, or I think I could answer some parts of this question: ✓
- Our class answered this question, or using the ideas we have developed, I could now answer this question: ✓✓

✱ ATTENDING TO EQUITY

Revisiting the Driving Question Board is important for students to feel as though their questions are valued and recognized. While not all questions will have been addressed (it is more likely that 50–75%will at least be partially answered), this helps students see the hard work that they have done to answer many of their own questions.

17 · REVISIT OUR DRIVING QUESTION BOARD (DQB)

25 min

MATERIALS: science notebook, *Let's Answer Questions from Our Driving Question Board!*, Driving Question Board, 3 colors of sticky dots

Mark patterns in questions answered using the sticky dots. Have students move into their Scientists Circle, bringing with them their science notebooks and *Let's Answer Questions from Our Driving Question Board!*. Once in the Scientists Circle, students will focus the discussion on the questions they agree we can answer, answer parts of the question, or not answer at all. Choose one color of sticky dot to mark each of these categories.

Discuss the questions the class can now answer.✱ Present **slide P** if needed. Have the class discuss the answers to those questions as a group. If you have space, you might make a "Takeaways" board that has a record of the answers with which the class comes up.

ASSESSMENT OPPORTUNITY	While students are answering questions from the Driving Question Board, this is an excellent formative assessment opportunity to address partial understandings and see if any pieces need to be revisited.

Celebrate the class's accomplishments.

✱ SUPPORTING STUDENTS IN ENGAGING IN ASKING QUESTIONS AND DEFINING PROBLEMS

Revisiting the DQB at the end of the unit helps students see the progress they have made toward answering questions that were important to them at the onset of the unit. Students were tasked with asking questions "that required sufficient and appropriate evidence to answer." Through the investigations in the unit and individual and whole-group sensemaking, they can now answer many of the questions. This final visit to the DQB also allows students to see how their hard work toward a shared learning goal helps them figure out the phenomenon and can also explain a lot of other phenomena in the world.

18 · QUICK WRITE: REFLECT ON OUR EXPERIENCES

15 min

MATERIALS: science notebook

Have students reflect on their experiences with the unit. Have students return to their regular seats. Prompt students to find a new page in their science notebooks and title the page: "Reflection." Display **slide Q**. Give students about 5 minutes to write a personal reflection on their learning based on the following prompts:

- What was most challenging in this unit?
- What was most rewarding?
- *Think about how you engaged in sensemaking discussions with classmates.* How would you want to engage with those experiences the next time you are part of a classroom community that is working to try to figure out answers to the questions the class

formed together, by investigating different sources of data and phenomena?

- What would you do the same?
- What would you do differently?

Then bring students together in a whole-group discussion to share one part of their reflection on the unit.

ADDITIONAL GUIDANCE	This unit asks students to do meaning-making that is difficult but potentially rewarding. Taking time to reflect on the process of this unit can allow students to think about what works well for them as learners. Consider giving more time to answer these questions if needed.
SUPPORTING STUDENTS IN MAKING CONNECTIONS IN ELA	**CCSS.ELA-Literacy.W.7.1.b Support claim(s) with logical reasoning and relevant evidence, using accurate, credible sources and demonstrating an understanding of the topic or text.** Part 8 of student's *Palm Farm Design* handout is a written explanation to support two design features of a better palm farm. Students should structure the explanation around claims about each design feature, how it functions, and support the claims with evidence from their design investigations and reasoning using science ideas developed in the unit.
SUPPORTING STUDENTS IN MAKING CONNECTIONS IN MATH	**CCSS.Math.Content.6.RP.A.1 Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities.** **CCSS.Math.Content.6.RP.A.3 Use ratio and rate reasoning to solve real-world and mathematical problems.** **CCSS.Math.Content.6.SP.A.1 Recognize a statistical question as one that anticipates variability in the data related to the question and accounts for it in the answers.** **Mathematical Practice MP.4 Model with mathematics.** On days 1, 2 and 4 of this lesson students engage in mathematical reasoning and computational thinking. Specifically this happens when students construct Gantt charts for crop selection on day 1 and test their selections adjusting ratios of farm land in the Crop Calculator Tool to try to find the best ratio per crop to stabilize a farmer's income. On day 4 students conduct multiple trials on their 4-farm design to stabilize, and even maximize, orangutan populations. They conduct multiple trials because the question they are investigating anticipates variability in their data.