Feeding the World - Human Populations

Science & Engineering Practices	**Disciplinary Core Ideas**	**Cross Cutting Concepts**
Using Mathematics and Computational Thinking	**LS2.C**: Ecosystem Dynamics, Functioning, and Resilience	Scale, Proportion and Quantity
Constructing Explanations and Designing Solutions	**ETS1.B**: Developing Possible Solutions	Stability and Change
	LS2.A: Interdependent Relationships in Ecosystems	Influence of Science, Engineering, and Technology on Society and the Natural World
	ESS3.C: Human Impacts on Earth Systems	

Feeding the World Human Populations Overview

This high school unit focuses on Analyzing and Interpreting Data, Using Mathematics and Computational Skills and Engaging in Argument from Evidence to understand the growth of human populations. Analyzing and Interpreting Data, Using Mathematics and Computational Skills and Engaging in Argument for Evidence are employed to teach this unit because population studies deal with many statistics, not just numbers of births and deaths, but economic development statistics as well. The process of Analyzing and Interpreting Data should take place in conjunction with other practices. Combined with these other Science and Engineering Practices, students are supported to make sense of the complexities of human population growth.

Lesson 1: *Population Growth*, introduces the number of people in the human population and the time frame in which they were born and lived. Students use Mathematics and Computational Skills to determine the rate at which the population increased. Lesson 2: *Population Age Structures*, builds on the Lesson 1, by introducing age structure pyramids, which are a graphical way to display population data by age groups, and are used to predict population growth. The Lesson 3: *Demographic Transition*, uses another model to help students understand the economic effects of development on human populations. Lesson 4: *Farming for the Future*, engages students in a simulation using subsistence farming, a labor-intensive method of farming used by the majority of farmers in the developing world to feed their families. Students will collect data to analyze, then use that data to suggest ways to improve this method of farming.

The *Next Generation of Science Standards (2013)* describes the importance of Analyzing and Interpreting Data as evidence to support one's conclusions. There are many ways to analyze and interpret data and scientists have a range of tools to analyze and interpret data, for example, in this unit students mimic the work of scientists by using age structure pyramids to predict population growth. Scientists work with data (evidence) toward the goal of answering a question, in this unit, students use the data from a simulation to determine if and how resource availability affects human population growth.

Mathematical and Computational Thinking is about relationships, in this unit students investigate various natural resources and several other geographic and demographic statistics then create a spreadsheet of these values to determine if there are relationships between or among these data points. Computational thinking is about processes; in Lesson 3, students will experiment with different ways these data points may be affected by one another. The *Next Generation of Science Standards (NGSS,* NGSS Lead States 2013) expect and anticipate that mathematics will be used to represent relationships and make predictions. Mathematics provides a tool to help us understand science, and therefore integration of these two subjects is important. Computers and other digital tools provide a useful mechanism for students to use mathematics and computational thinking.

In Lesson 4, Students will use the practice of Constructing Explanations and Designing Solutions combined with Using Mathematics and Computational Skills and Analyzing and Interpreting Data to create an explanation based on the data they collected. This practice encourages students to evaluate a method they have experienced (in the simulation) and suggest new solutions for the problems encountered.

These lessons were developed to be used together to encourage students to think critically about the food productions system that is used most often throughout the world and develop ideas about how we might feed over nine billion people in 2050. The lessons were designed around the practices as follows in this chart below:

Science and Engineering Practices
Lesson 1: Population Growth **Mathematics & Computational Thinking**
Lesson 2: Population Age Structures **Analyzing & Interpreting Data**
Lesson 3: Demographic Transition **Mathematics & Computational Thinking**
Lesson 4: Farming for the Future **Constructing Explanations and Designing Solutions**

Resources

Alston, J.M. and Pardey, P.G. (2009). "Theme Overview: Agricultural Productivity And Global Food Security In The Long Run". Choices. Retrieved from: http://www.choicesmagazine.org/UserFiles/file/article_90.pdf

Biswas, S. (2014) "India's dark history of sterilisation". BBC News. Retrieved from: https://www.bbc.com/news/world-asia-india-30040790

ChartsBin (2010). Total Water Use per capita by Country http://chartsbin.com/view/1455

FAO (2009). *How to Feed the World in 2050*. Retrieved from: http://www.fao.org/fileadmin/templates/wsfs/docs/expert_paper/How_to_Feed_the_World_in_2050.pdf

FAO (2012) "Labour". Retrieved from: http://www.fao.org/docrep/015/i2490e/i2490e01b.pdf

FAO (2018). *The State of Food Security and Nutrition in the World.* Retrieved from: http://www.fao.org/state-of-food-security-nutrition/en/

Frazer, E. (1992). "Thailand: A Family Planning Success Story" Context Institute. Retrieved from: https://www.context.org/iclib/ic31/frazer/

Grover, D. (2014). "What is the Demographic Transition Model?" Published online at Population Education.org. Retrieved from: https://populationeducation.org/what-demographic-transition-model/

[ICIPE] (2015). *Climate Smart Push-Pull technology by ICIPE* (International Centre of Insect Physiology and Ecology) [Video file] Retrieved from https://www.youtube.com/watch?v=XY_m-gemNMw

Krajcik, J. (2012). Preparing for NGSS: Engaging in Argument from Evidence [PowerPoint slides]. Retrieved from https://learningcenter.nsta.org/products/symposia_seminars/NGSS/files/PreparingforNGSS--EngaginginArgumentfromEvidence_12-4-2012.pdf

Menker, S. (2017). *A global food crisis may be less than a decade away*. TED. [Video file] Retrieved from https://www.youtube.com/watch?v=OzA6jRYjVQs

[PUR project] (2014). *Agroforestry Benefits* [Video file] Retrieved from https://www.youtube.com/watch?v=aHD3G4fXm5o

Rosenberg, M, (2018) “China's Former One-Child Policy”. Thought Co. Retrieved from: https://www.thoughtco.com/chinas-one-child-policy-1435466

Roser, M. (2018). "Employment in Agriculture". *Published online at OurWorldInData.org.* Retrieved from: https://ourworldindata.org/employment-in-agriculture

Roser, M and Ortiz-Ospina, E. (2018). "World Population Growth". *Published online at OurWorldInData.org.* Retrieved from: https://ourworldindata.org/world-population-growth

Rosling, H. (2012). *Religion and babies.* TEDX Summit. [Video file] Retrieved from https://www.ted.com/talks/hans_rosling_religions_and_babies

Rosling, H. (2010). *Global Population Growth*. TED@Cannes. [Video file] Retrieved from https://www.ted.com/talks/hans_rosling_on_global_population_growth

Searchinger, T. et al. (2013). “The Great Balancing Act.” Working Paper, Installment 1 of Creating a Sustainable Food Future. Washington, DC: World Resources Institute. Available online at http://www.worldresourcesreport.org

[Southern Africa Trade Hub] (2016). *USAID Helps Launch Powerful New System for Farmers in Malawi, Mozambique, and Zambia* [Video file] Retrieved from https://www.youtube.com/watch?v=n1GG3MJSNSw

[Ted Ed] (2014). *Population pyramids: Powerful predictors of the future* [Video file] Retrieved from https://www.youtube.com/watch?v=RLmKfXwWQtE

USDA graph: Corn for Grain Yield (2018) Retrieved from: https://www.nass.usda.gov/Charts_and_Maps/graphics/cornyld.pdf

USDA graph: Soybean Yield (2018) Retrieved from: https://www.nass.usda.gov/Charts_and_Maps/graphics/soyyld.pdf

[World Agroforestry Centre] (2017). *Dreams come true: the benefits of agroforestry*. [Video file] https://www.youtube.com/watch?v=PQXpPmeDh3Q&t=1s

[World Bank] (2008). *Rice Farming in Afife, Ghana* [Video file] Retrieved from https://www.youtube.com/watch?v=UrddBks41IY

World Population Clock Live by The World Counts http://www.theworldcounts.com/counters/shocking_environmental_facts_and_statistics/world_population_clock_live

World Population History https://worldpopulationhistory.org/map/2050/mercator/1/0/25/

[246 productions] (2010). *Subsistence Farming* [Video file] Retrieved from https://www.youtube.com/watch?v=jlBu-qaNMMg

3rd World Farmer: A thought-provoking simulation https://3rdworldfarmer.org/

Feeding the World Human Populations - Storyline

Lesson/Routine	Questions	Phenomena/Problems	What We Figured Out
Anchoring Phenomena		World Population Clock https://worldpopulationhistory.org/map/2050/mercator/1/0/25/	• This clock tracks births on earth. • This counter increases by about 200,000 every day.
Lesson 1 Population Growth	• How many people are added in a minute? • How many people are added in our state? • How many people are added in the United States? • Where are people added in the world?	Students Analyze and Interpret Data to see how fast population increases. Resource availability does not seem to limit the growth of human populations in the same way as other organisms. Why is that?	Human population grew slowly up until 1960, then has increased rapidly since then, adding a billion every 12-14 years.
Lesson 2 Population Age Structures	• Where are all the people? • Why do populations grow so fast? • How can we predict population growth?	Population grows fastest in areas of the world that have the fewest resources or infrastructure.	Students use graphical representations in order to Analyze and Interpret Data to determine where the growth of populations is located in the world.
Lesson 3 Demographic Transition	• How do countries develop and change? • What effect do those developments and changes have on populations? • How do these changes affect the eating habits	Countries have changed over time through economic development. Those changes have an effect on how people work, live and eat.	As countries develop economically, their death rates decline, then their birth rates, then their food consumption patterns - turning more to higher protein foods.

	of those populations?		
Lesson 4 Farming for the Future	● What percent of the world population is engaged in agriculture? ● What type of agriculture is most frequently used? ● How might farming change to help feed the world? ● Will feeding the world lead to more population growth?	People who rely on subsistence farming are taking chances on weather, the types of crops to plant and the limits of yield. Education, infrastructure and health care is lacking in many of these countries.	While more than 2/3 of the population in poor countries work in agriculture, less than 5% of the population does in rich countries. The increase in productivity allows for fewer people to be involved in working on farms and makes it possible to reduce the agricultural land needed to feed a given number of people.

Pre-/Post Assessment

Feeding the World and Human Population Growth

1. The human population is:
   A. Growing
   B. Declining
   C. Stable

2. Which of the following statements is true?
   A. The countries with the largest populations grow the fastest.
   B. The countries with the largest populations over 45 grow the fastest
   C. The countries with the largest populations under 15 grow the fastest.
   D. The countries with the largest populations between 15 and 45 grow the fastest.

3. If we feed all the people in the world, what will happen to the rate of growth of the world population?
   A. It will grow right away.
   B. It will decline right away.
   C. There will be no change in the current rate of growth.
   D. It will decline over time.

4. Subsistence farming methods create: (circle all that apply)
   A. Problems for the local ecosystem
   B. Enough food for local populations
   C. Enough food for regional and national populations
   D. Less than enough calories to feed all who depend on these methods

5. The total human population increases each day by:
   A. About 100,000 people
   B. About 200,000 people
   C. About 500,000 people
   D. About 1 million people

6. Which of the following factors impact human population growth?
   A. Birth rate
   B. Death rate
   C. Economic development
   D. Education level
   E. All of these
   F. None of these

Lesson 1: Population Growth - Teacher

Essential Questions: *How fast has population increased over human history? What might help slow the rate of increase?*

DCI

LS2.A: Interdependent Relationships in Ecosystems	
Performance Expectations	Classroom Connections
HS-LS2-1. Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.	Students identify and describe the components in the given mathematical and/or computational representations (e.g., trends, averages, histograms, graphs, spreadsheets) that support given explanations of factors that affect carrying capacities of ecosystems at different scales. The components include: i. The population changes gathered from historical data.
Science & Engineering Practices Using Mathematics and Computational Thinking ● Use mathematical and/or computational representations of phenomena or design solutions to support explanations.	Students use given mathematical and/or computational representations (e.g., trends, averages, histograms, graphs, spreadsheets) of ecosystem factors to identify changes over time in the numbers of humans in countries of different sizes.
Disciplinary Core Idea **LS2.A: Interdependent Relationships in Ecosystems** ● Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges such as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of	Ecosystems have carrying capacities. Students use mathematics and computational thinking to determine if humans have reached carrying capacity.

individuals) of species in any given ecosystem.	
Crosscutting Concept Scale, Proportion, and Quantity ● The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.	Students analyze and use the given mathematical and/or computational representations i. To identify the interdependence of factors (both living and nonliving) and resulting effect on carrying capacity; and ii. As evidence to support the explanation and identify the factors that have the largest effect on the carrying capacity of an ecosystem for a given population.

Background
According to most estimates, there will be 9.5 billion people on the planet in 2050. Many experts suggest that growers will have to produce more food in the next 50 years than has been grown in the past 10,000, which is doubling current production on the same amount of land. Yield increases have begun to slow (see USDA graph). Therefore, this demand will require new technologies, new techniques and new environmental practices be developed.

What are the limits to the food production possibilities? The amount of **arable** land may decrease if climates continue to change. Water is limited around the world and the places that are most productive are not necessarily in the areas where food is most needed. Fossil fuels, even with the addition of **ethanol**, run tractors while fertilizers and pesticides are also energy intensive to create. Therefore, food production is closely tied to fuel costs and availability.

Another concern is the **infrastructure** that is necessary to get food to markets before it spoils. In many less economically developed countries, there is no system to get the food to market and storing it is not a viable option due to fungus and pests spoiling it. Soil is also vulnerable to erosion, desertification (once fertile land becomes arid), salinization (build-up of salts in the soil from over-irrigation) and water-logging (saturation of soil by groundwater).

One of the largest problems in the developed world is food waste. Some of the crop is lost in the field to pests (about 30%), some is left during the harvest (10–20%), and in the U.S., it is estimated that consumers throw away as much of 50% of their food. Population pressures are driving today's food production demand. While the need to feed a growing population will continue, factors such as decreasing infant mortality rates, reducing the need for children to work, providing women with educational opportunities and access to family planning will improve the standard of living in countries worldwide and increase the demand for food. With 9 billion eaters, the agriculture industry, made up of large-scale farmers, local food producers, entrepreneurs, agricultural scientists and engineers will all become allies in meeting future food demands.

Phenomena
Begin the lesson with a one minute look at the World Population Clock: http://www.theworldcounts.com/counters/shocking_environmental_facts_and_statistics/world_population_clock_live This site shows a live count of the people being added to the world population.

Have students brainstorm questions individually for 30 seconds to one minute, then share their questions within small groups (3-4 students) for two-three minutes. Have groups share their questions one-by-one until all questions are shared. Keep note of the questions, as they will guide the rest of this unit.

Possible questions:

- How many people are added in a minute?
- How many people are added in our state?
- How many people are added in the United States?
- Where are all of these people?
- What is the rank of countries by population?
- Why are some countries growing faster than others?
- What are the effects of this growth?
- What effects do the growth of human populations have on ecosystems?
- Do we have enough food?
- Can we grow enough food?
- When did we grow so large as a human population?

If no one brings up food or food production, add your own questions: Do we have enough food to feed everyone? Where are the people and where is the food? How can we feed 9.8 billion people in 2050, and what happens along the way?

To begin investigating these questions, organize the ones that relate to the sheer number of people and the rate at which the population has grown.

See these resources for additional information:
https://ourworldindata.org/world-population-growth
https://worldpopulationhistory.org/map/2050/mercator/1/0/25/
http://www.theworldcounts.com/counters/shocking_environmental_facts_and_statistics/world_population_clock_live

Use Lesson 1: **Population Growth** to address some of those questions.

Materials
Students will need an electronic device to access the internet.
Students will work individually to complete the following steps.

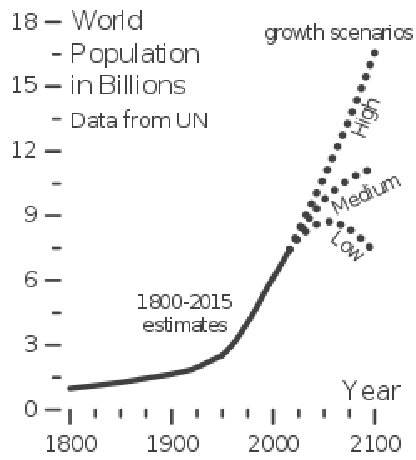
Procedures
1. Have students research the information by visiting https://worldpopulationhistory.org/map/2050/mercator/1/0/25/

Ask:
- How many years has it taken for the world population to double? Double again? When is it predicted to double again?
- How many years has it taken for the world population to increase by each 1 billion?

2. Students create their own table or use the example one (on separate page as part of student lesson) to collect data on the years it has taken to reach each billion and to double.

Year	Population in billions	Number of years between	Years to double
1804	*1 billion*	*many*	
1928	*2 billion*	*124*	*124*
1960	*3 billion*	*32*	
1974	*4 billion*	*14*	*56*
1987	*5 billion*	*13*	
1999	*6 billion*	*12*	
2011	*7 billion*	*12*	
Estimated 2023	*8 billion*	*Estimated 12*	*Estimated 49*

3. *Possible Graph*



https://commons.wikimedia.org/wiki/File:World_population_v3.svg

Differentiation

Other ways to connect with students with various needs:

i. **Local community**: students may investigate the population changes in their town, city, state or home country (https://census.gov/ to access local data)

ii. **Students with special needs (language/reading)**: Teacher may supply a table and/or graph for students to interpret or only require the mathematical calculation without the graph.

iii. **Extra support**: students may model exponential growth by using objects (seeds, blocks, etc) to show rapid increase as numbers increase, or complete pedigrees of their own families from grandparents to their own generations. (ties to local community also)

iv. **Extensions**: Students can compare birth rates from previous decades to see the change over time, and how the growth rate has slowed, but the numbers are still adding up exponentially.

Reflection

1. What might account for the decreasing time between billions?

Possible answers: more people to have children, increased life span and lower infant mortality

2. How have humans utilized land resources to increase food production to allow for these increases?

Possible answers: better farming methods, use of technology, cleared more land from forests

3. What are the effects of technology when used in food production?

Possible answers: increased yield, more efficiency by reducing time (using tractors and harvesters), less labor needed

4. What factors must be considered to project future growth?

Possible answers: cultural factors, limits imposed by governments, number of women of childbearing age, age at marriage, education of women, child mortality rates (the higher the mortality rate, the higher the rate of population increase), women in the workforce...

Assessment

Have human populations reached carrying capacity? Write a paragraph to:

- Identify any interdependence of factors (both living and nonliving) and the resulting effect(s) on carrying capacity; and
- identify the factors that have the largest effect on the carrying capacity of an ecosystem for a human population as evidence to support your explanation.

Rubric for assessment

Skill	Beginning	Satisfactory	Exemplar
Use mathematical and/or computational representations of phenomena or design solutions to support explanations.	Carrying capacity is defined, but not used correctly. Two factors are listed as interdependent factors	Carrying capacity is defined correctly in paragraph. Two or more factors (either living or nonliving) are listed and the impacts they have on carrying capacity of human populations are explained	Carrying capacity is defined and used appropriately to describe the impact of humans on the scale of a single ecosystem up to the Earth. Two or more factors (either living or nonliving) are listed and the impacts they have on carrying capacity of human populations are explained and evidence is given for the factor with the largest impact

Rubric for self-assessment

Skills	Yes	No
Carrying capacity is a concept I understand and I can explain and apply the concept to human populations.		
I used mathematical or computational thinking to provide evidence to answer the question: Have human populations reached carrying capacity?		

Lesson 1: Population growth

Essential Questions: *How fast has population increased over human history? What might help slow the rate of increase?*

Vocabulary

Carrying capacity -

What living and nonliving factors impact human carrying capacity?

Materials

Device with internet access

Procedure

1. Go to https://worldpopulationhistory.org/map/2050/mercator/1/0/25/

2. Create a table to record the year in which population increased by 1 billion. Add a third column to record the number of years it took to increase by 1 billion. Using the interactive map, determine the year the population increased by 1 billion. Calculate the number of years it took to increase by 1 billion or to double (where appropriate).

3. Graph these results on an app or by hand on graph paper. (Assessment)

Reflection

1. What might account for the decreasing time between billions?

2. How have humans utilized land resources to increase food production to allow for these increases?

3. What are the effects of technology when used in food production?

4. What factors must be considered to project future growth?

Assessment

Have humans reached carrying capacity? Write a paragraph to:

- Identify any interdependence of factors (both living and nonliving) and the resulting effect(s) on carrying capacity; and
- identify the factors that have the largest effect on the carrying capacity of an ecosystem for a given population as evidence to support your explanation in your answer.

Rubric for assessment

Skill	Beginning	Satisfactory	Exemplar
Use mathematical and/or computational representations of phenomena or design solutions to support explanations.	Carrying capacity is defined, but not used correctly. Two factors are listed as interdependent factors	Carrying capacity is defined correctly in paragraph. Two or more factors (either living or nonliving) are listed and the impacts they have on carrying capacity of human populations are explained	Carrying capacity is defined and used appropriately to describe the impact of humans on the scale of a single ecosystem up to the Earth. Two or more factors (either living or nonliving) are listed and the impacts they have on carrying capacity of human populations are explained and evidence is given for the factor with the largest impact

Rubric for self-assessment

Skills	Yes	No
Carrying capacity is a concept I understand and I can explain and apply the concept to human populations.		
I used mathematical or computational thinking to provide evidence to answer the question: Have human populations reached carrying capacity?		

Resources

https://ourworldindata.org/world-population-growth
https://worldpopulationhistory.org/map/2050/mercator/1/0/25/
http://www.theworldcounts.com/counters/shocking_environmental_facts_and_statistics/world_population_clock_live

Example Table:

Year	Population in billions	Number of years between	Years to double
	1 billion		
	2 billion		
	3 billion		
	4 billion		
	5 billion		
	6 billion		
	7 billion		
	8 billion		

Population age structures - Teacher

Essential Questions: *What is an age structure diagram? How does age structure affect population growth? Why is this important in food production?*

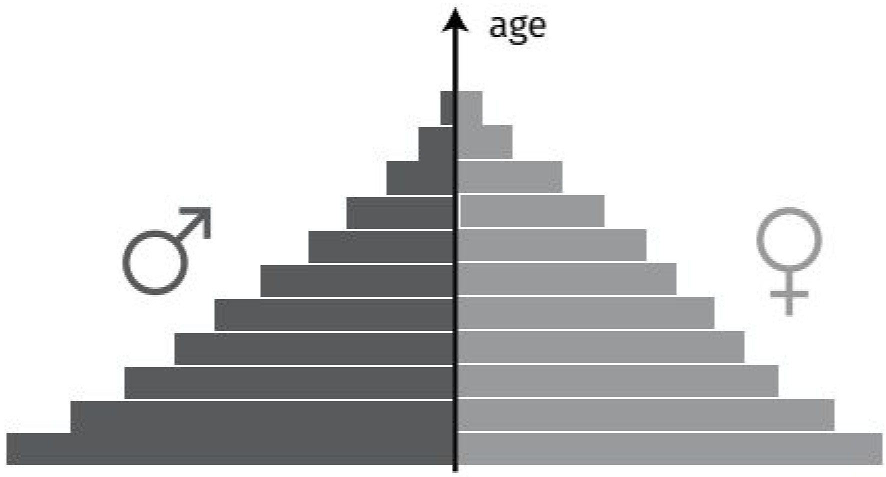
DCI

HS-LS2.A: Interdependent Relationships in Ecosystems

Performance Expectation	Connections to Activity
HS-LS2-2. Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales. ● [CS: Examples of mathematical representations include finding the average, determining trends, and using graphical comparisons of multiple sets of data.]	Students use mathematical representations (population age structures) to identify and predict changes over time in the numbers of humans within the countries.
Science & Engineering Practice	
Using Mathematics and Computational Thinking ● Use mathematical representations of phenomena or design solutions to support and revise explanations.	Students use computational thinking to determine how the population age structures are important mathematical representations that predict and explain population growth in various countries.
Disciplinary Core Idea	
LS2.A: Interdependent Relationships in Ecosystems ● Ecosystems have carrying capacities, which are limits to	Students identify the given explanation(s) supported by factors affecting human carrying capacity (i.e.

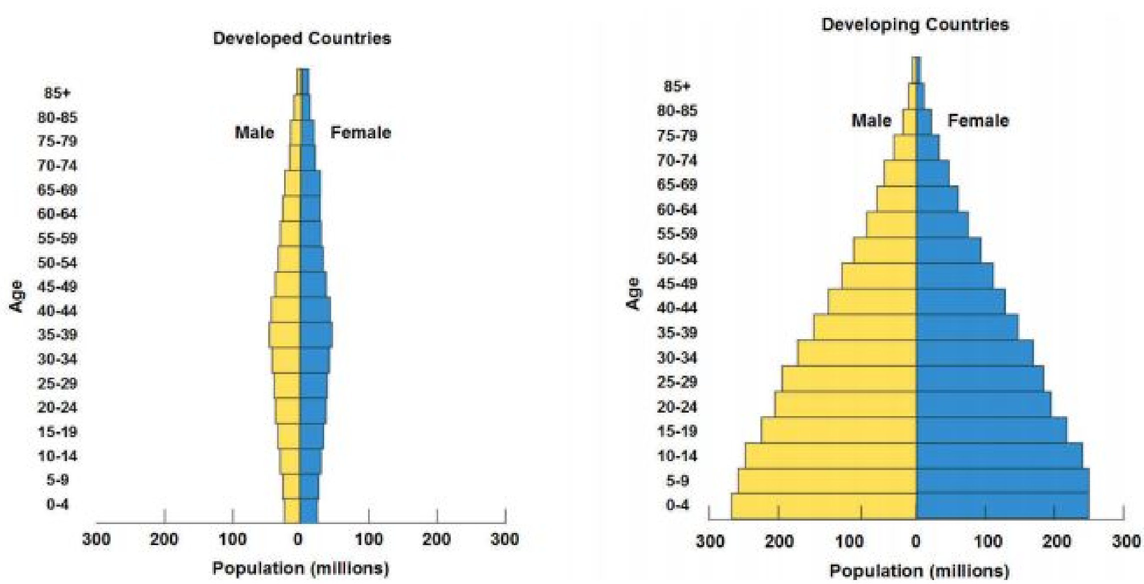
the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges such as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem.	the number of humans in the population vary as a function of the physical and biological dynamics of the ecosystem) which includes food security, child mortality and other factors.
Cross Cutting Concept	
Scale, Proportion, and Quantity ● Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale.	Students compare age structure diagrams among countries with different populations to see the difference in numbers/scale/proportion.

A population age structure diagram is the proportion of the population (and of each gender) at each age level. (Each level in the above graphic represents an age group in increasing order, youngest at the bottom and oldest at the top.)



1. Draw two lines on the pyramid above.
a. The first line should be drawn above the third level of the pyramid which encompasses the pre-reproductive age group, 0–14.
b. The second line includes the next six levels, so draw above the ninth level of the pyramid and is the reproductive age group (15–44).
c. Above the line drawn in b is the post-reproductive age group (44–85+).

These diagrams help to determine how a country's population will grow. Take a look at the two structures below:



2. Which of the structures above show imminent population growth?

Answer: The one on the right

The percentage (or the actual number) of the population that is of reproductive age is the percentage that will be responsible for increasing population, in addition to the percentage that will be reaching reproductive age in the following years. In the diagram to the left, the reproductive population is much smaller and there are fewer children in the age categories below the reproductive age groups. As you might think, the populations of less developed countries are increasing at a greater rate than those of developed countries. In addition, a larger number of malnourished people also live in those developing countries. Almost all the hungry people, 780 million, live in developing countries, representing 12.9 percent, or one in eight, of the population of developing countries. There are 11 million people undernourished in developed countries (FAO 2015; for individual country estimates, see Annex 1).

3. What are the implications of rapidly growing populations and more malnourished people in developing countries? What might a country do to decrease population growth? What has been done (i.e. China, Thailand, India policies)?

> *Possible Answers:* more people in less developed countries lead to more food insecurity, worsening health problems, more children struggling in school where education is accessible…
>
> Countries have taken various approaches to slowing population growth - China required one child for many years (1979-2015); people were penalized if they had more than one child (https://www.thoughtco.com/chinas-one-child-policy-1435466). Thailand offered birth control to their population from 1971-1992 and lowered their population growth rate from 3.2%-1.6%. (https://www.context.org/iclib/ic31/frazer/) India tried forced sterilizations in the 1970's (and still conducts sterilizations - 4 million in 2013-2014) that result in many people suffering from complications related to the surgeries. (https://www.bbc.com/news/world-asia-india-30040790)

In 1798, Thomas Robert Malthus predicted that short-term gains in living standards would be undermined as human population growth outstripped food production, and create a population crash. However, we have not seen this to be the case. Over the last half-century, world population doubled while food supply tripled, even as land under cultivation grew by only 12% (FAO, 2012). It is by raising productivity, or getting more output from existing resources, that has been driving growth in global agriculture, and what has proven Malthus wrong. In fact, at the global level, the long-run trend since at least 1900 has been one of increasing food abundance—in inflation-adjusted dollars, food prices fell by an average of 1% per year over the course of the 20th Century - See more at: http://www.choicesmagazine.org/choices-magazine/submitted-articles/productivity-growth-in-global-agricultureshifting-to-developing-countries#sthash.G3Uw6q0Z.dpuf

Read the three statements below:

> a. Agriculture employs over 1.3 billion people throughout the world, or close to 40 percent of the global workforce.

b. In about 50 countries, agriculture employs half of the population, and even 75 percent in the poorer nations.
c. Agriculture is the world's largest provider of jobs.
http://www.momagri.org/UK/agriculture-s-key-figures/With-close-to-40-%25-of-the-global-workforce-agriculture-is-theworld-s-largest-provider-of-jobs-_1066.html

4. In light of the predictions of Malthus, the realities of food production since 1900, including the Green Revolution and new technologies which include genetic modification of various types, and precision agriculture techniques, what is your prediction about food production in the next 30 years? What strategies can we continue to use, or develop, to meet the needs of growing populations and changing demographics?

Possible Answers: food production will get more efficient; there is a movement in developed countries to go back to smaller scale farming and locally sourcing food; economies of scale may be applied to developing countries as they are in developed countries; Infrastructure needs to be improved; Distribution networks need to be developed; vertical gardens could be employed where feasible...

Differentiation

Other ways to connect with students with various needs:

i. **Local community**: students may investigate the population age structures in their town, city, state or home country (U.S.- https://census.gov/ Access Local Data)
ii. **Students with special needs (language/reading)**: Structures may be increased in size for easier determination of numbers in each age group.
iii. Extra support: Video: https://www.youtube.com/watch?v=RLmKfXwWQtE *Population pyramids: Powerful predictors of the future - Kim Preshoff* This video helps to combine this lesson and the following one on Demographic Transition. There is also a lesson plan here:
https://ed.ted.com/lessons/population-pyramids-powerful-predictors-of-the-future-kim-preshoff
iv. Extensions: Students can research previous events that have affected the population changes (i.e. World War II, changing cultural norms in a country, etc.)

Reflection

1. Looking at the countries that have the largest potential for population growth, what are the causes of their large population growth?

   Possible Answers: more people in the reproductive age groups, lack of education of women, infant and child mortality, lack of access to contraception...

2. Are these causes related to resource availability? Why do you think this?

   Possible Answers: Yes, resources including health care, education, technology, etc.

3. What are the ecosystem limits?

Possible Answers: We may not know until it is too late (*Collapse* by Jared Diamond: “Twilight at Easter”); it is difficult to predict because we have not exceeded the limits but we can see the signs of overgrazing, soil salinization, desertification...

4. What can humans do to address those limitations?

   Possible Answers: technology that allows for growing food in non-native environments; genetic modification; precision farming methods that help to lessen the impact on ecosystems while still growing food

Assessment

How well do age structure diagrams predict growth of populations within countries? Are there other models that would work as well or better? What factors do age structure diagrams take into account? Are these factors always going to be predictive of population growth?

Rubric for assessment

Skill	Beginning	Satisfactory	Exemplar
Use mathematical representations (population age structures) to identify and predict changes over time in the numbers of humans within the countries.	Unable to read and interpret the mathematical representation (age structure diagram)	Able to read, analyze and interpret the meaning of an age structure diagram; ability to predict population growth	Able to read, analyze and interpret the meaning of the diagram; ability to make prediction from the diagram and identify the limitations of the predictive ability.

Rubric for self-assessment

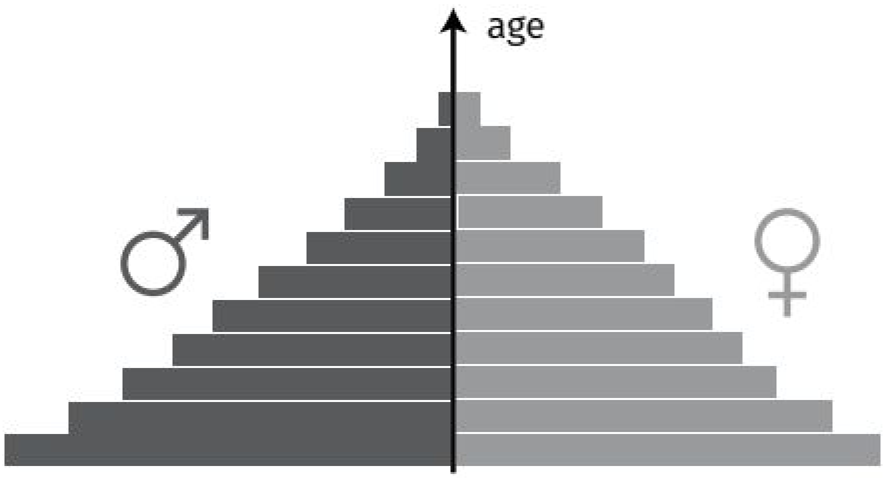
Skill	Yes	No
I can read an age structure diagram.		
I can predict human population growth using an age structure diagram.		
I can list the limitations of an age structure diagram to predict human population growth		

Additional resources:
Hans Rosling - Religion and babies
https://www.ted.com/talks/hans_rosling_religions_and_babies
Hans Rosling - Global Population Growth
https://www.ted.com/talks/hans_rosling_on_global_population_growth

Population age structures

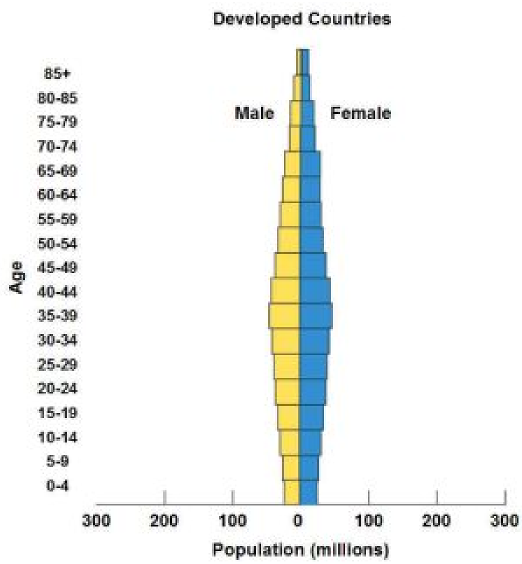
Essential Questions: *What is an age structure diagram? How does age structure affect population growth? Why is this important in food production?*

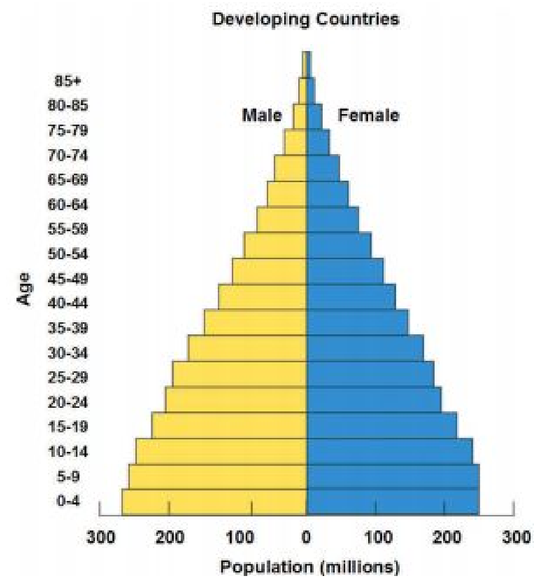
A population age structure diagram is the proportion of the population (and of each gender) at each age level. (Each level in the above graphic represents an age group in increasing order, youngest at the bottom and oldest at the top.)



1. Draw two lines on the pyramid above.
a. The first line should be drawn above the third level of the pyramid which encompasses the pre-reproductive age group, 0–14.
b. The second line includes the next six levels, so draw above the ninth level of the pyramid and is the reproductive age group (15–44).
c. Above the line drawn in b is the post-reproductive age group (44–85+).

These diagrams help to determine how a country's population will grow. Take a look at the two structures below:





2. Which of the structures above shows imminent population growth?

The percentage (or the actual number) of the population that is of reproductive age is the percentage that will be responsible for increasing population, in addition to the percentage that will be reaching reproductive age in the following years. In the diagram to the left, the reproductive population is much smaller and there are fewer children in the age categories below the reproductive age groups. As you might think, the populations of less developed countries are increasing at a greater rate than those of developed countries. In addition, a larger number of malnourished people also live in those developing countries. Almost all the hungry people, 780 million, live in developing countries, representing 12.9 percent, or one in eight, of the population of developing countries. There are 11 million people undernourished in developed countries (FAO 2015; for individual country estimates, see Annex 1).

3. What are the implications of rapidly growing populations and more malnourished people in developing countries? What might a country do to decrease population growth? What has been done (i.e. China, Thailand, India policies)?

In 1798, Thomas Robert Malthus predicted that short-term gains in living standards would be undermined as human population growth outstripped food production, and create a population crash. However, we have not seen this to be the case. Over the last half-century, world population doubled while food supply tripled, even as land under cultivation grew by only 12%

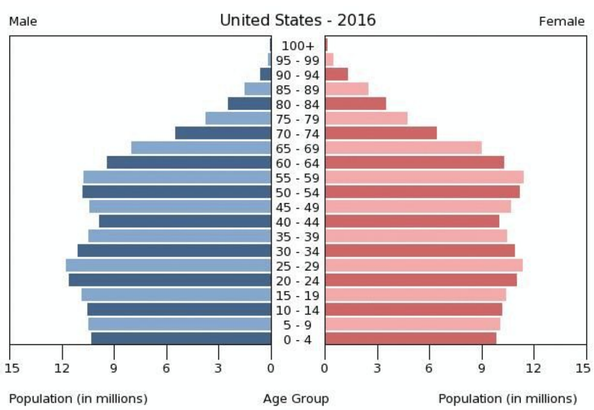
(FAO, 2012). It is by raising productivity, or getting more output from existing resources, that has been driving growth in global agriculture, and what has proven Malthus wrong. In fact, at the global level, the long-run trend since at least 1900 has been one of increasing food abundance—in inflation-adjusted dollars, food prices fell by an average of 1% per year over the course of the 20th Century - See more at: http://www.choicesmagazine.org/choices-magazine/submitted-articles/productivity-growth-in-global-agricultureshifting-to-developing-countries#sthash.G3Uw6q0Z.dpuf

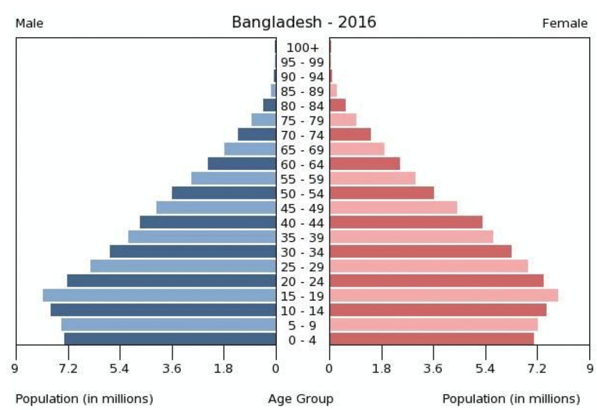
Read the three statements below:

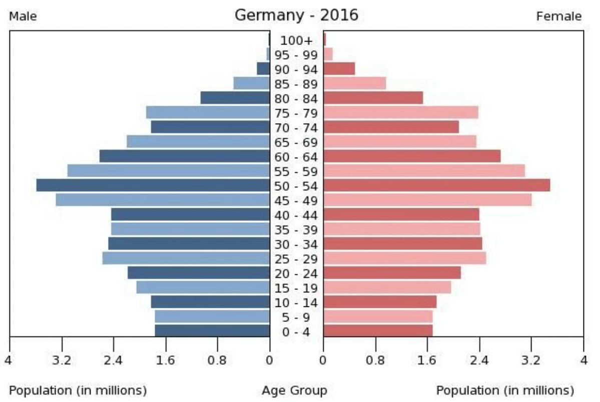
a. Agriculture employs over 1.3 billion people throughout the world, or close to 40 percent of the global workforce.
b. In about 50 countries, agriculture employs half of the population, and even 75 percent in the poorer nations.
c. Agriculture is the world's largest provider of jobs.
http://www.momagri.org/UK/agriculture-s-key-figures/With-close-to-40-%25-of-the-global-workforce-agriculture-is-theworld-s-largest-provider-of-jobs-_1066.html

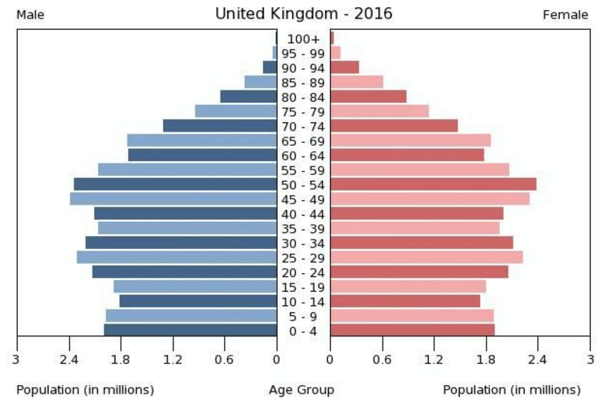
4. In light of the predictions of Malthus, the realities of food production since 1900, including the Green Revolution and new technologies which include genetic modification of various types, and precision agriculture techniques, what is your prediction about food production in the next 30 years? What strategies can we continue to use, or develop, to meet the needs of growing populations and changing demographics?

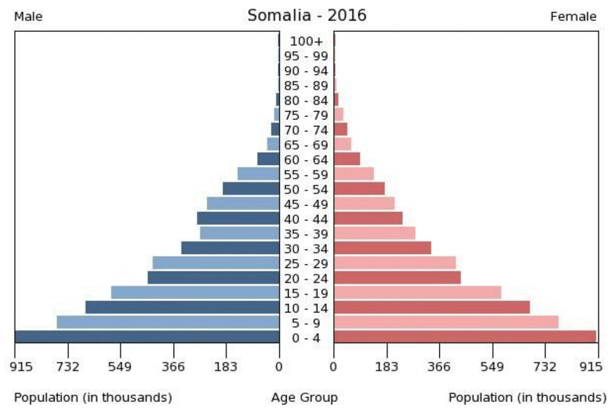
Look at the age structures below to predict the growth of the populations in those countries as high, medium, low or negative.

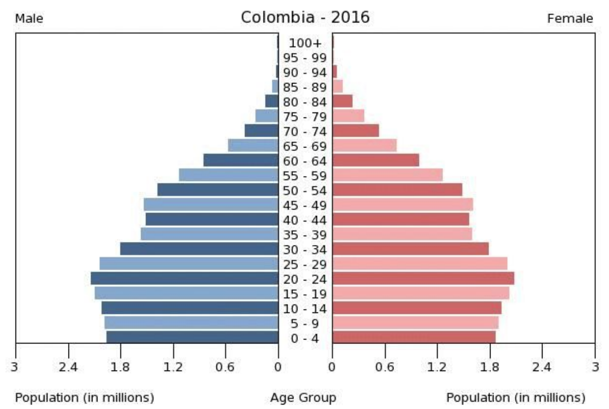


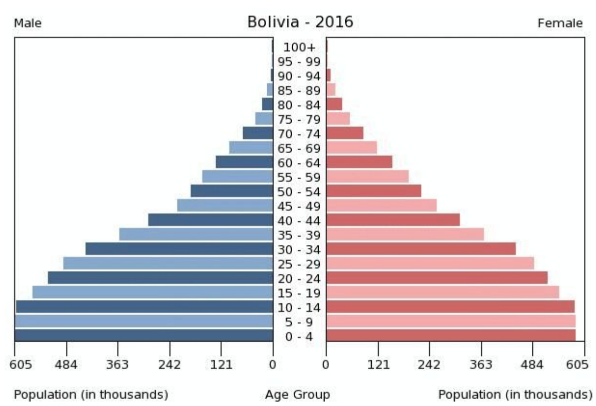












Visit the site: https://www.indexmundi.com to compare the actual numbers of individuals in each age group.

Reflection

1. Looking at the countries that have the largest potential for population growth, what are the causes of their population growth?
2. Are these causes related to resource availability?
3. What are the ecosystem limits?
4. What can humans do to address those limitations?

Assessment

How well do age structure diagrams predict growth of populations within countries? Are there other models that would work as well or better? What factors do age structure diagrams take into account? Are these factors always going to be predictive of population growth?

Rubric for assessment

Skill	Beginning	Satisfactory	Exemplar
Use mathematical representations (population age structures) to identify and predict changes over time in the numbers of humans within the countries.	Unable to read and interpret the mathematical representation (age structure diagram)	Able to read, analyze and interpret the meaning of an age structure diagram; ability to predict population growth	Able to read, analyze and interpret the meaning of the diagram; ability to make prediction from the diagram and identify the limitations of the predictive ability.

Rubric for self-assessment

Skill	Yes	No
I can read an age structure diagram.		
I can predict human population growth using an age structure diagram.		
I can list the limitations of an age structure diagram to predict human population growth		

Lesson 3: Demographic Transition - Teacher

Essential Questions: *What demographics change as economies develop? How does demographic transition affect the kinds of foods and resources demanded?*

DCI (Standard)

HS-ESS3.C Human Impacts on Earth's Systems	
Performance Expectation	**Classroom Connections**
HS-ESS3-3: Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity. [CS: Examples of factors that affect the management of natural resources include per-capita consumption and the development of new technologies. Example of a factor that affects human sustainability includes agricultural efficiency.]	Students research land and water use as well as other factors to create a spreadsheet that illustrates the relationships between human populations and the sustainability of human populations.
Science & Engineering Practice	
Using Mathematics and Computational Thinking ● Create a computational model or simulation of a phenomenon, designed device, process, or system.	Students describe simplified realistic (corresponding to real-world data) relationships between researched variables to indicate an understanding of the factors (e.g., costs, availability of technologies) that affect the management of natural resources, human sustainability, and biodiversity.
Disciplinary Core Idea	
ESS3.C: Human Impacts on Earth Systems	Students research effects of increased production/consumption of food and the

• The sustainability of human societies and the biodiversity that supports them requires responsible management of natural resources	impacts of that increased consumption of food and production of food on ecosystems while meeting the needs of the human populations for food.
Cross Cutting Concept	
Influence of Science, Engineering, and Technology on Society and the Natural World • All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment.	Students investigate the availability of technologies to people in various countries; investigate the technologies that have been developed to reduce the human impact of food production systems.

This lesson was designed to follow Lesson 2: *Population Growth* and *Population Age Structures*. It includes information about the same countries highlighted in Lesson 2. Students will get a comprehensive view of the countries by researching the factors that contribute to population growth along with the economics in order to create a computational model to describe trends within, among and between countries. This lesson is designed to be assigned to each individual student and they should research information on multiple countries in order to create the spreadsheet to show relationships.

The background below does not appear on the student handout, but can be shared with students, depending on teacher objectives.

This video: *A global food crisis may be less than a decade away* with Sara Menker https://www.youtube.com/watch?v=OzA6jRYjVQs helps to describe a different way of framing the question "How do we feed 9 billion people in 2050?" Sara Menker uses calories and lists which countries are net calorie exporters and which are importers of calories. It helps to explain the economic conditions that lead to demographic transition. Her group has created a website See also: https://populationeducation.org/what-demographic-transition-model/ for additional explanation about the demographic transition model. This website also provides a case study for each stage of the model 2-5.

Background

By 2050 the world's population will reach 9.8 billion, about 30 percent higher than today's population. Nearly all of this population increase will occur in developing countries.

Urbanization will continue at an accelerated pace, and about 70 percent of the world's population will be urban (compared to 49 percent today). In order to feed this larger, more urban population, food production must increase by 60-70 percent. Urbanization brings with it changes in lifestyles and consumption patterns. In combination with income growth it may accelerate changes in the diets of people in developing countries. Currently, these populations depend heavily on grains: maize, wheat and rice. While the shares of grains and other staple crops will be declining, those of vegetables, fruits, meat, dairy, and fish will increase. In response to this change, these groups will be increasingly buying food from markets where there is more of a concentration on secondary consumers (animals that eat the grains). However, rural areas will still be home to the majority of the poor and hungry for quite some time. Currently, one billion people cannot even satisfy their basic needs in terms of food energy.
http://www.fao.org/fileadmin/templates/wsfs/docs/expert_paper/How_to_Feed_the_World_in_2050.pdf

Feeding these additional billions by 2050 is a formidable challenge, with tighter resource constraints (land, water, soil), the demand to limit agriculture's ecological footprint and the impact of climate change. Many have argued that distribution is the problem and if we could solve that, there is enough production to feed the world population now (http://pdf.wri.org/great_balancing_act.pdf). Current global food availability is not sufficient to feed the world in 2050, even if all the food calories available in the world today were equally distributed across the projected population in 2050. With the changes that will be demanded by a growing urban population (as described above), this idea is not feasible. Boosting farm productivity is an essential instrument to alleviating poverty and reducing hunger.

Reducing food waste and encouraging less resource-intensive diets in developed countries (particularly lower meat consumption) are desirable goals, but they do not reduce the need to invest in increasing agricultural production and improving agricultural productivity in both developed and developing countries.
http://www.iiea.com/blogosphere/global-population-projections-and-food-demand

Population growth is determined by the birth rate and death rate within the country. Growth rate can be calculated by using the formula: birth rate/1000-death rate/1000

1. Choose one of the countries below to evaluate. Estimate what stage of transition the country is in on the DT model. Use evidence when explaining the position on the model.

		United States	Bang-ladesh	UK	Germany	Som-alia	Colom-bia	Bolivia
Birth rate	1990	17/1000	35/1000	14/1000	11/1000	48/1000	26/1000	35/1000

	2018	12/1000	19/1000	12/1000	9/1000	39/1000	16/1000	22/1000
Death rate	1990	9/1000	10/1000	11/1000	12/1000	20/1000	6/1000	13/1000
	2018	8/1000	5/1000	9/1000	12/1000	13/1000	6/1000	6/1000
Natural increase*	1990	0.8%	2.5%	0.3%	negative rate of growth	2.8%	2%	1.2%
	2018	0.4%	1.4%	0.3%	negative rate of growth	2.6%	1%	1.6%
Stage on Demo Transition		*Stage 5*	*Stage 3 or 4*	*Stage 5*	*This model does not show*	*Stage 2 or 3*	*Stage 4*	*Stage 3*

* Natural increase = $\frac{(BR – DR)}{1000}$ * 100 (expressed as a percent)

2. What is the status of freshwater and land use in the countries included above?
    a. Use ciafactbook.gov to find land use for agriculture data and amount of irrigated land (Geography)
    b. What is the percent of the population working in agriculture? (Economy)
    c. Research other sites to find the amount of freshwater resources and compare to the population. (http://www.fao.org/nr/water/aquastat/data/query/index.html?lang=en)
    d. Research how much water is used per capita for domestic use (http://chartsbin.com/view/44463)
    e. Use https://www.nationalgeographic.com/what-the-world-eats/ to determine caloric consumption of food for each country.

Students should be encouraged to choose other stats to help them determine what factors contribute to ecosystem impacts. Students need to determine what mathematical relationships exist between factors that describe the countries that have high population growth rates and resources use. High school students need to determine if there are mathematical relationships using factors that describe the countries that have high population growth rates and resources use.

United States

Land use for agriculture	9,147,593 sq km*44.5% = 4,070,679 sq km
Amount of irrigated land	264,000 sq km
% working in Ag	160.4 million*0.7%=1.13 million
Freshwater resources	2818 $10^9 m^3$
Domestic water use per capita	1,550m^3/year
Problems	
Population	329,256,465
Population below the poverty line	15.1% or 49.7 million
Calories consumed	3641 kcal/person

Notes: Third largest country in terms of population.

Bangladesh

Land use for agriculture	130,170 sq km*70.1%=91,249 (most arable)
Amount of irrigated land	53,000 sq km
% working in Ag	66.64 million*43%=28.7 million
Freshwater resources	105 $10^9 m^3$
Domestic water use per capita	224 m^3/year
Problems	
Population	159,453,001
Population below the poverty line	24% or 38,268,720
Calories consumed	2270 kcal/person

Notes:

UK

Land use for agriculture	241,930 sq km*71%=171,770 sq km
Amount of irrigated land	950 sq km
% working in Ag	33.5 million*1.3%=435,500

Freshwater resources	145 $10^9 m^3$
Domestic water use per capita	212.5 m^3/year
Problems	
Population	65,105,246
Population below the poverty line	15% or 9.8 million
Calories consumed	3413 kcal/person

Notes:

Germany

Land use for agriculture	348,672 sq km*48%=167,363 sq km
Amount of irrigated land	6500 sq km
% working in Ag	45.9 million*1.4%=642,600
Freshwater resources	107 $10^9 m^3$
Domestic water use per capita	392.3 m^3/year
Problems	
Population	80,457,737
Population below the poverty line	16.7% or 13,334,442
Calories consumed	3539 kcal/person

Notes:

Somalia

Land use for agriculture	627,337 sq km*70.3%=441,017 sq km (mostly pasture)
Amount of irrigated land	2000 sq km
% working in Ag	4.154 million*71%=2.95 million
Freshwater resources	6 $10^9 m^3$
Domestic water use per capita	378 m^3/year

Problems	Desert, drought
Population	11.26 million
Population below the poverty line	73% or 8.2 million
Calories consumed	1695 kcal/person

Notes:

Colombia

Land use for agriculture	1,038,700 sq km*37.5%=389,512.5 sq km (mostly pasture)
Amount of irrigated land	10,900 sq km
% working in Ag	25.76 million*17%=4.3792 million
Freshwater resources	2,145 $10^9 m^3$
Domestic water use per capita	308 m^3/year
Problems	Five River basins Water is used for hydropower Demand for water outstrips the inadequate capacity caused by insufficient infrastructure Extensive pollution from industrial and agricultural activities and lack of sewage treatment.
Population	48,168,996
Population below the poverty line	28% or 13.4 million
Calories consumed	2690

Notes:

Bolivia

Land use for agriculture	1,083,301 sq km * 34.3%=371,572 sq km (mostly pasture)
Amount of irrigated land	3000 sq km
% working in Ag	5,719,000*29.4%=1.681 million
Freshwater resources	303.5 $10^9 m^3$

Domestic water use per capita	234 m^3/year
Problems	Fresh water contamination by sewage and deforestation (leading to sediment pollution)
Population	11 million
Population below the poverty line	39% or 4.29 million
Calories consumed	2100 kcal/person

Notes: Bolivia is one of the poorest countries in the Western Hemisphere

Differentiation

Other ways to connect with students with various needs:

i. **Local community**: students may investigate the demographic changes in their city, state (i.e. a business invests in a new plant (Honda or Toyota) or a plant shuts down (Kodak or a steel mill).

ii. **Students with special needs (language/reading/auditory/visual)**: Students may be asked to research information for one or two countries, then combine their information with other students to create a class spreadsheet. Students would then manipulate to determine calculations/mathematical relationships.

iii. **Extra support**: Teacher may provide background information to students to help them understand the model more fully. Teachers may show this video: *Population pyramids: Powerful predictors of the future - Kim Preshoff* (https://www.youtube.com/watch?v=RLmKfXwWQtE). This video helps to combine this lesson and Lesson 2: *Population Age Structures*. There is also a lesson plan for discussion with students here: https://ed.ted.com/lessons/population-pyramids-powerful-predictors-of-the-future-kim-preshoff

iv. **Extensions**: Students can research previous economic events that have affected the population changes (i.e. post-WWII baby boom in U.S., Russian governmental changes after the fall of Communism, etc.)

Reflection

1. As a country develops, according to this model, what trends do you see in population statistics?

Possible answers: death rates fall first, then birth rates; an initial rise in population growth rate, then a drop

2. As a country develops, what happens to the kinds of foods people eat (How do eating habits change)? See: https://www.nationalgeographic.com/what-the-world-eats/

Possible answers: people generally begin to eat at higher levels on the energy pyramid: i.e. instead of eating grains or plant-based foods, people being to eat animals that eat the plant-based foods (beef, chicken, pork) depending on the culture/religion

3. What negative effects might those eating habits have on the environment, the economy, food production?

Possible answers: animals that eat plant-based foods need grazing land, larger amounts of water and higher amounts of waste; meat is more expensive than plant-based foods; food production becomes more specialized by concentrating livestock operations and grain operations in different areas; however, efficiencies are increased and food generally has a higher protein content, lowering malnutrition.

4. How might humans increase crop production without increasing water use or amount of crop land?

Possible answers: use of biotechnology, advanced irrigation techniques like drip irrigation that will lower the amount of water lost to evaporation; precision ag techniques like soil testing and using soil amendments only where needed, reducing fuel use, etc.

5. What technologies have contributed to the demographic transition modeled in this diagram?

Possible answers: tractors and harvesters have lowered the number of people needed to grow food; better health care and access to drugs for treatment of and curing diseases; access to education for women, etc.

Assessment

Develop a computational model to compare these data points (i.e. compare the data from each country to other countries to determine if relationships exist between countries; and compare the effects of certain pieces of data on others.) Include data that were researched as well as those that were supplied. Include other factors that you think may have an effect.

- For example: If the growth rate of a population changes, what effect might that have on the number of calories consumed? How about on the use of freshwater per person per year?

(See sample spreadsheet for a beginning/satisfactory chart comparing 2 countries)

Rubric for Assessment

Skill	Beginning	Satisfactory	Exemplar
Use mathematical, computational, and/or algorithmic representations of data Apply ratios, rates, percentages, and unit conversions in the context of	Spreadsheet created, but no mathematical calculations/functions applied	Spreadsheet created with data provided and countries compared to one another using mathematical relationships (i.e % more/less, fraction of size, etc)	Spreadsheet created with data provided; additional data added; mathematical functions applied to show relationships between and among data.

complicated measurement problems involving quantities with derived or compound units			

Rubric for Self-Assessment

Skill	Yes	No
I can create a spreadsheet and enter data in the proper format.		
I can use a spreadsheet to calculate mathematical relationships between the same types of data to compare countries.		
I can use mathematical functions to determine relationships between and among pieces of data.		

Extension

After completing the Demographic Transition activity, find three countries that are in Stage 2 or 3 on the Demographic Transition Model. Visit http://www.fao.org/state-of-food-security-nutrition/en/ to see which regions are suffering from food insecurity. Using ciafactbook.gov or other similar sources, research the economies of the countries that have the largest potential for population growth. What are the causes of food insecurity (be sure to look at multiple aspects, such as infant mortality, education of women and social norms)?

- What are the negative impacts of increased production and consumption of food resources?
- How have we tried to address these impacts?

Resources used to provide information in this document

https://www.nationalgeographic.com/what-the-world-eats/
http://www.fao.org/nr/water/aquastat/data/query/index.html?lang=en
http://chartsbin.com/view/44463
https://en.wikipedia.org/wiki/List_of_countries_by_food_energy_intake

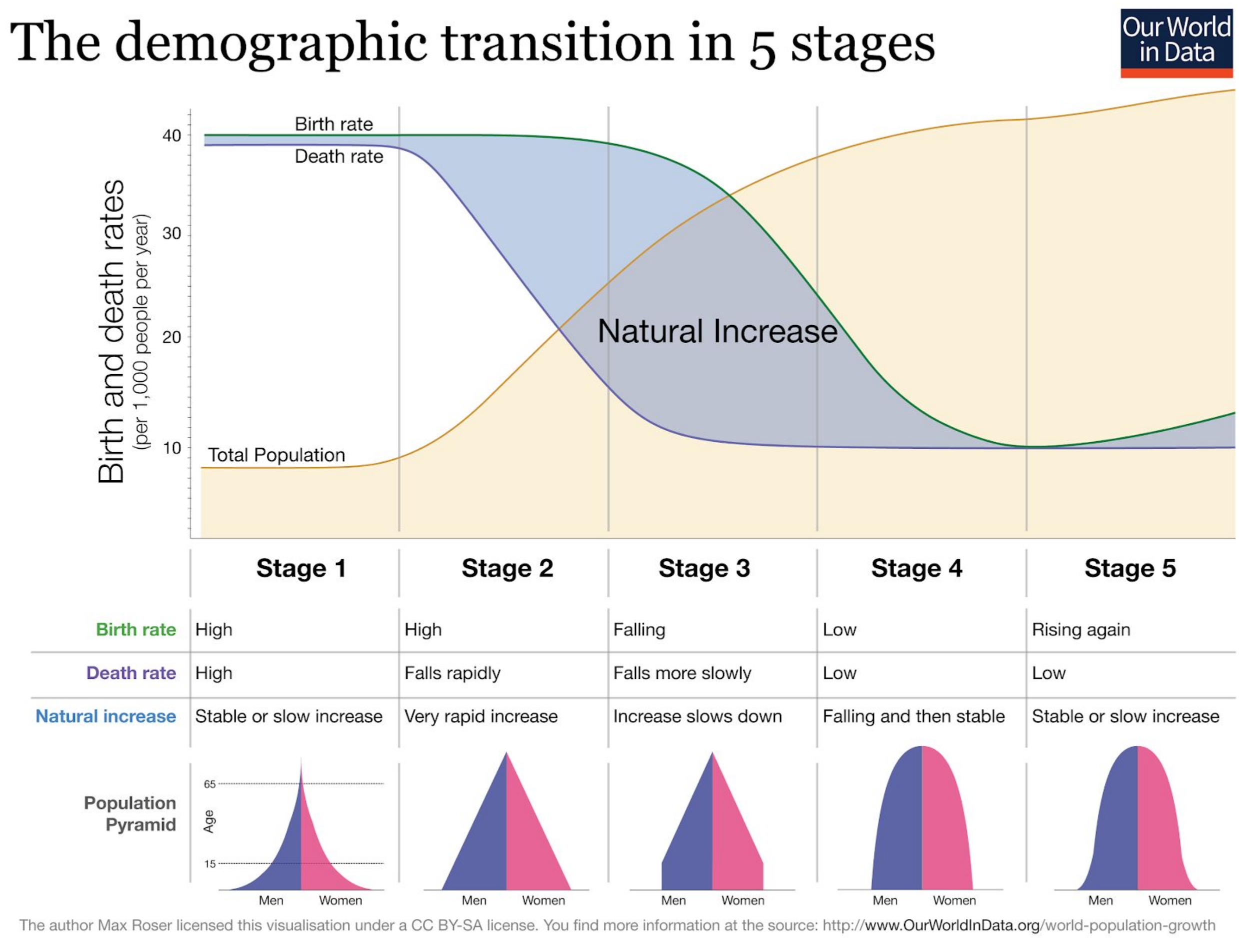
https://worldview.stratfor.com/article/colombia-abundant-water-brings-no-security
https://www.sam.usace.army.mil/Portals/46/docs/military/engineering/docs/WRA/Bolivia/FINAL%20BOLIVIA%20WRA%20COMBINED%2013%20DEC%202004.pdf

Lesson 3: Demographic Transition

Essential Questions: *What demographics change as economies develop? How does demographic transition affect the kinds of foods and resources demanded?*

Once a country begins to industrialize or as its economy develops, there are changes that occur in the demographics or statistics of the country. These statistics include birth rate, death rate, infant mortality and average income.

The Demographic Transition (DT) model is pictured below. Take a few moments to make observations about what is happening during each phase of the model.



https://ourworldindata.org/wp-content/uploads/2013/05/Demographic-TransitionOWID-with-pyramids-1.png

1. Choose each of the countries below to evaluate. Estimate what stage of transition the country is in on the DT model. Use evidence when explaining the position on the model.

		United States	Bang-ladesh	UK	Germany	Som-alia	Colum-bia	Bolivia
Birth rate	1990	17/1000	35/1000	14/1000	11/1000	48/1000	26/1000	35/1000
	2018	12/1000	19/1000	12/1000	9/1000	39/1000	16/1000	22/1000
Death rate	1990	9/1000	10/1000	11/1000	12/1000	20/1000	6/1000	13/1000
	2018	8/1000	5/1000	9/1000	12/1000	13/1000	6/1000	6/1000
Natural increase*	1990	0.8%	2.5%	0.3%	negative rate of growth	2.8%	2%	1.2%
	2018	0.4%	1.4%	0.3%	negative rate of growth	2.6%	1%	1.6%
Stage on Demo Transition								

* Natural increase = $\frac{BR - DR}{1000}$ * 100 (expressed as a percent)

2. What is the status of freshwater and land use in the countries above?
    a. Use ciafactbook.gov to find land use for agriculture data and amount of irrigated land (Geography)
    b. What is the percent of the population working in agriculture? (Economy)
    c. Research other sites to find the amount of freshwater resources and compare to the population. (http://www.fao.org/nr/water/aquastat/data/query/index.html?lang=en)
    d. Use https://www.nationalgeographic.com/what-the-world-eats/ to determine caloric consumption of food for each country.
    e. Include any additional information that seems to have a relationship to human impact, population growth and food production

Reflection

1. As a country develops, according to this model, what trends do you see in population statistics?

2. As a country develops, what happens to the kinds of foods people eat (How do eating habits change)?

3. What negative effects might those eating habits have on the environment, the economy, food production?

4. How might humans increase crop production without increasing water use or amount of crop land?

5. What technologies have contributed to the demographic transition modeled in this diagram?

Assessment

Develop a computational model to compare these data points (i.e. compare the data from each country to other countries to determine if relationships exist between countries; and compare the effects of certain pieces of data on others.) Include data that were researched as well as those that were supplied. Include other factors that you think may have an effect.

- For example: If the growth rate of a population changes, what effect might that have on the number of calories consumed? How about on the use of freshwater per person per year?

Rubric for Assessment

Skill	Beginning	Satisfactory	Exemplar
Use mathematical, computational, and/or algorithmic representations of data Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units	Spreadsheet created, but no mathematical calculations/functions applied	Spreadsheet created with data provided and countries compared to one another using mathematical relationships (i.e % more/less, fraction of size, etc)	Spreadsheet created with data provided; additional data added; mathematical functions applied to show relationships between and among data.

Rubric for Self-Assessment

Skill	Yes	No
I can create a spreadsheet and enter data in the proper format.		
I can use a spreadsheet to calculate mathematical relationships between the same types of data to compare countries.		
I can use mathematical functions to determine relationships between and among pieces of data.		

Lesson 4: Farming for the Future - Teacher

Adapted from an activity developed by Facing the Future (https://www.facingthefuture.org)

Essential Questions: *How many people farm in the world? What are the practices that the majority of global farmers use?*

HS-LS2.C: Ecosystem Dynamics, Functioning, and Resilience

Performance Expectations	**Connections to Activity**
HS-LS2-7. Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity. ● (C.S. Examples of human activities can include urbanization, building dams, and dissemination of invasive species.)	Students engage in a subsistence farming simulation. Upon completion of the simulation, students evaluate and refine solutions for addressing problems encountered using these methods.
Science & Engineering Practice	
Constructing Explanations and Designing Solutions ● Design, evaluate, and refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade-off considerations.	Following the simulation, students will design a solution that involves reducing the negative effects of human activities on the environment and biodiversity, and that relies on scientific knowledge of the factors affecting changes and stability in biodiversity (i.e. overpopulation, overexploitation, and climate change)
Disciplinary Core Idea	
LS2.C: Ecosystem Dynamics, Functioning, and Resilience ● Anthropogenic changes (induced by human activity) in the environment — including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate	Students develop solutions that help subsistence farmers become more efficient and better producers, compare these methods to industrial farming methods and explore the effects of food production on the environment.

change — can disrupt an ecosystem and threaten the survival of some species. ETS1.B: Developing Possible Solutions ● When evaluating solutions it is important to take into account a range of constraints including cost, safety, reliability and aesthetics and to consider social, cultural and environmental impacts. (secondary)	Students evaluate the cost, safety, and reliability, as well as social, cultural, and environmental impacts, of the proposed solution for a select human activity that is harmful to an ecosystem.
Cross Cutting Concept	
Stability and Change ● Much of science deals with constructing explanations of how things change and how they remain stable.	Students refine the proposed solutions by prioritizing the criteria and making tradeoffs as necessary to further reduce environmental impact and loss of biodiversity while addressing human needs. Students evaluate difficulties with the subsistence farming model and barriers to improvements.

Background
Over 43% of the world labor force in 1991 was dedicated to agriculture, but as of 2018, it is down to about 25%, with the number much higher in less developed countries, but much lower (about 2%) in more developed countries like the United States. Mechanization and technology has accounted for much of the change, yet there are many countries with over 50% of their labor force still dedicated to a **subsistence** farming method that has been practiced for thousands of years. This method relies on growing enough food for the family or village to get them to the next growing season, and is not always successful.

The **infrastructure** that exists in the United States that allows farmers to sell their grain or livestock in one state that will be made into food products that will be distributed across the region or even the world does not exist in less developed countries. In those countries, access to electricity can be a large barrier to drying grains so they do not spoil. Trucks and roadways may be lacking that would allow for travel to a regional market. Sometimes, consumers like products from other regions better (see: https://www.youtube.com/watch?v=UrddBks41IY).

Students engage in this simulation to see the differences between commodity farming as it exists in the US and subsistence farming as it may exist in a less developed country. They will collect data about yields and malnutrition, then analyze the data to determine if human populations are limited by their resources and how humans have overcome some of those limitations.

Students will participate in groups of 3-5 to form a village. They will work together to make decisions about what crops to plant and where to plant them.

Materials

One four-sided die for each group
One set of instructions for each group
Data sheets for each group
One set of impact cards for Round 1 and Round 2 for the entire class
One set of impact cards for Round 3 for the entire class
One Effects of Malnutrition chart for each group
Photos of the crops that are being planted. (Many students are unfamiliar with these crops.)

Reflection

1. How successful were you at growing enough food for your village?
   Possible answers: Answers will vary and are due to chance; ask students how the answers are so different between groups...all villages may not be in the same region, the weather conditions and impact cards will not be the same
2. How is this simulation realistic? Not realistic?
   Possible answers: Realistic: Much of farming is up to the weather and the choice of crops, Unrealistic: education will vary among villagers and markets may be more accessible for some than others; impact cards are skewed negatively in the first two rounds, but improvements are possible in the third
3. What suggestions would you recommend to an NGO to provide for your village?
   Possible answers: Provide education so all can read, provide methods that rely on available technology (cell phones), provide a forum to share village successes, provide birth control to lower population growth, etc...
4. Describe 3 specific differences between this farming simulation and commodity farming as it is practiced in the United States.
   Possible answers: Tractors and harvesters are used in US (more access to fuel and machinery), access to fertilizer and pesticides, soil characteristics are different, some farmers plant only one or two crops, do not need to feed the family or village from their fields
5. What can the village learn from the United States?
   Possible answers: use the information to improve crop selection (GMOs) and crop rotation; fertilizers and pesticides help improve yield, but can be overused; soil is a precious resource; scale and efficiency may be helpful, but will not feed the village directly
6. What can the United States learn from your village?
   Possible answers: working together can help increase yield; improved methods on small scale may be applied on a large scale; feeding people locally is possible
7. What did you learn from completing this simulation?
   Possible answers: Answers will vary

Differentiation

Other ways to connect with students with various needs:

i. **Local community**: students may investigate the farming methods used in their town, county or state.

ii. **Students with special needs (language/reading/auditory/visual)**: For students who are not interested in working in groups or who do better on their own try *3rd World Farmer* simulation (https://3rdworldfarmer.org/) o see how successful they might be.

iii. **Extra support**: Video: *Subsistence Farming* (https://www.youtube.com/watch?v=jlBu-qaNMMg) This video has no dialogue, but shows two of the labor practices necessary to subsistence farming: clearing a weed patch and planting rice.

iv. **Extensions**: Students can compare subsistence farming methods to those used in commodity farming most often in the United States. This text reading gives some background. https://www.opengeography.org/ch-6-food-water-and-agriculture.html with the following addendum about GMO crops: long-term studies on public health have not been confirmed yet. See: http://nas-sites.org/ge-crops/category/report/ which has found no negative effects of GM crops on health. Or, students can investigate methods being used to improve subsistence farming, [i.e. Agroforestry (http://www.worldagroforestry.org/) *Dreams come true: the benefits of agroforestry*- using trees intercropping to improve soil (https://www.youtube.com/watch?v=PQXpPmeDh3Q&t=1s), *Push Pull Agriculture* - striga weed, desmodium and napier grass, used along with maize; stem borer and wasps produced by the International Center for Insect Physiology and Ecology (https://www.youtube.com/watch?v=XY_m-gemNMw) *Warehouse Receipts Systems* to store and sell grain (https://www.youtube.com/watch?v=n1GG3MJSNSw)]

Assessment

Design a solution/set of solutions that reduce the negative effects of human activities on the environment and biodiversity, and that relies on scientific knowledge of the factors affecting changes and stability in biodiversity (i.e. overpopulation, overexploitation, and climate change). Evaluate the cost, safety, and reliability, as well as social, cultural, and environmental impacts, of the proposed solution for this method of farming. Refine the proposed solutions by prioritizing criteria and making tradeoffs as necessary to further reduce environmental impact and while addressing human needs. Use the questions below to guide your thinking.

1. How does this method of farming with the limitations you encountered, meet the needs of the people using these methods?
   Possible answers: It may be able to feed the people in the village without relying on outside sources; it may meet cultural needs (providing work for villagers, keeping people fed, etc)

2. How might the methods of subsistence farming lead to problems that may increase the size of populations in areas where there are using these methods?
   Possible answers: If child mortality is high due to high malnutrition and poor sanitation, the likelihood that villagers will have more children to be sure some make it to adulthood will increase; if access to health care is poor, that will affect the child mortality rate; if education is lacking for all (or especially women) the birth rate may increase;

3. What new methods might be used? How might those methods impact the ecosystem?
   Possible answers: Agroforestry and push pull methods of agriculture will improve soils and allow for raising livestock as the trees will provide fodder; these methods in combination use natural biological properties to help crops to grow without pest problems

4. What are the barriers to using new methods?
   Possible answers: Access to tractors and harvesters; access to electricity and other technology; learning about new methods and gaining access to new crops; unfamiliarity with GMOs and their benefits

5. How might the introduction of technology reduce these barriers?
   Possible answers: Technology may allow farmers to access information and gain access to markets.

Rubric for Assessment

Skill	Beginning	Satisfactory	Exemplar
Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade-off considerations.	Participated in the subsistence farming simulation; solution to subsistence farming as a method to produce food is vague or missing.	Participated in the subsistence farming simulation; a specific solution or set of solutions included that will lessen the impact of subsistence farming and increase food production efficiency.	Participated in the subsistence farming simulation; a specific set of solutions included that will lessen the impact of subsistence farming and increase food production efficiency with priorities for implementation and consideration of barriers to implementation.

Rubric for Self-Assessment

Skill	Yes	No
I participated in the farming simulation with my group and collected data on yield.		
I can suggest a solution for lessening the impact of subsistence farming on the environment.		
I can suggest a set of solutions for increasing food production efficiency.		
I can prioritize the solutions and predict the barriers to		

implementing my solutions.		

Lesson 4: Farming for the Future

Adapted from an activity developed by Facing the Future (https://www.facingthefuture.org)

Essential Questions: *How many people farm in the world? What are the practices that the majority of global farmers use?*

Nearly three fourths of all farms worldwide are less than one hectare (about 2.5 acres). Just over ten percent of all farms are between 2.5-5 acres. Only one percent of farms are over 125 acres.
(http://www.globalagriculture.org/report-topics/industrial-agriculture-and-small-scale-farming.html)

In Nebraska, the average farm size is 934 acres while the United States has an overall average farm size of 441 acres (USDA, 2015). Different methods of farming are used on the farms in Nebraska and in the United States, than are used in other countries of the world, particularly developing ones.

In groups of 3 - 5, you will make farming decisions as a "village" determining what crops to plant in which of your 10 fields. Your production will be affected by events that are out of your control (I.e. government stability, corruption, weather events)

Instructions

1. Your village has 10 small fields to plant.
2. You must plant at least **three different crops** to ensure a variety of food types and at least **two fields must be protein crops**. Label the fields where you plant each crop on the year 1 plot.
3. Determine your yields based on the weather dice roll: 1, 2, 3, 4 = dry year; 5, 6 = wet year 4. Use a pencil to fill out the worksheet.
5. Choose an impact card, read it aloud, and calculate impact losses. (Some impacts will affect all villages and some will affect only your village.)
6. Determine the effect of malnutrition based on your final total yield and the Effects of malnutrition chart.
7. Repeat activity for year 2 and year 3.

Reflection

1. How successful were you at growing enough food for your village?

2. How is this simulation realistic? Not realistic?

3. What suggestions would you recommend to an NGO to provide for your village?

4. Describe 3 specific differences between this farming simulation and commodity farming as it is practiced in the United States.

5. What can the village learn from the United States?

6. What can the United States learn from your village?

7. What did you learn from completing this simulation?

Assessment

Design a solution/set of solutions that reduce the negative effects of human activities on the environment and biodiversity, and that relies on scientific knowledge of the factors affecting changes and stability in biodiversity (i.e. overpopulation, overexploitation, and climate change). Evaluate the cost, safety, and reliability, as well as social, cultural, and environmental impacts, of the proposed solution for this method of farming. Refine the proposed solutions by prioritizing criteria and making tradeoffs as necessary to further reduce environmental impact and while addressing human needs. Use the questions below to guide your thinking.

1. How does this method of farming with the limitations you encountered, meet the needs of the people using these methods?

2. How might the methods of subsistence farming lead to problems that may increase the size of populations in areas where there are using these methods?

3. What new methods might be used? How might those methods impact the ecosystem?

4. What are the barriers to using new methods?

5. How might the introduction of technology reduce these barriers?

Rubric for Assessment

Skill	Beginning	Satisfactory	Exemplar
Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade-off considerations.	Participated in the subsistence farming simulation; solution to subsistence farming as a method to produce food is vague or missing.	Participated in the subsistence farming simulation; a specific solution or set of solutions included that will lessen the impact of subsistence farming and increase food production efficiency.	Participated in the subsistence farming simulation; a specific set of solutions included that will lessen the impact of subsistence farming and increase food production efficiency with priorities for implementation and consideration of barriers to implementation.

Rubric for Self-Assessment

Skill	Yes	No
I participated in the farming simulation with my group and collected data on yield.		
I can suggest a solution for lessening the impact of subsistence farming on the environment.		
I can suggest a set of solutions for increasing food production efficiency.		
I can prioritize the solutions and predict the barriers to implementing my solutions.		