Using NASA Earth-observing Satellites to Help Improve Agriculture and Water Usage
Middle School

"Water for Wheaties?" Lesson Plan

Lesson Overview:
The overall goal for this lesson plan is to introduce students to STEM-related careers. Students will learn about Earth's freshwater resources and how NASA's Earth observing satellites are helping us better understand Earth's water. They will work in small "expert groups" to explore growing wheat, the differences in weather and climate in two wheat farming regions of the world, Pakistan and Kansas, and the scarcity of freshwater resources in Pakistan. Using this information, students will get into "teams" and work with NASA data from the GPM (Global Precipitation Measurement) mission to explore the amount of precipitation that has fallen in these two regions over the past two decades. They will make recommendations for how farmers in Pakistan could reduce their water usage based on the work that is being done by Faisal Hossain. They will also learn how GPM data is being used to provide micro-insurance policies to small farmers in developing countries to help ensure they will recover their losses in case of extreme drought or flooding. Finally, they will consider ways they can reduce their use of freshwater resources in their own lives.

Time Required: This lesson can take from three to four 45-minute class periods, depending on how in depth the teacher decides to get into the data analysis part of the lesson and how many of the extension activities are included.

Anchor Phenomenon: How do farmers make sure they have enough water for their crops? What are some career opportunities which involve science, technology, and mathematics and helping people to improve their lives and preserve freshwater resources?

NGSS:
The performance expectations in middle school help students formulate answers to questions such as: "*How is the availability of needed natural resources related to naturally occurring processes*?, *How can natural hazards be predicted*, *How do human activities affect Earth systems?*, *How does a system of living and non-living things operate to meet the needs of the organisms in an ecosystem?*"

This lesson will introduce, reinforce, or give additional content information to support the following MS level NGSS:

- **MS-LS1-5.** Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.
- **MS-LS1-6.** Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms.
- **MS-LS1-6.** Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms.
- **MS-LS2-5.** Evaluate competing design solutions for maintaining biodiversity and ecosystem services.
- **MS-ESS2-4.** Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity.
- **MS-ESS2-5.** Collect data to provide evidence for how the motions and complex interactions of air masses result in changes in weather conditions.
- **MS-ESS2-6.** Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.
- **MS-ESS3-1**. Construct a scientific explanation based on evidence for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience processes.
- **MS-ESS3-2**. Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.
- **MS-ESS3-3.** Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.
- **MS-ESS3-4.** Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.
- **MS-ETS1-1.** Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- **MS-ETS1-2.** Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

Background Information:

NASA has many Earth observing satellites that are studying Earth's systems. You can learn more about these missions here. The GPM (Global Precipitation Measurement) mission is a NASA mission that is measuring Earth's precipitation around the world.

The data from this mission is being used in a wide variety of ways, from helping weather forecasters better predict hurricanes to responding to natural disasters to improving health around the world.

In this lesson, we will focus on how GPM data are being used by Faisal Hossain to help wheat farmers reduce their use of precious freshwater resources. They will learn about the work he does as a Professor of Civil and Environmental Engineering, and learn more about his STEM-related career. They will also learn about the work being done by Iker Llabres, who develops micro-insurance policies to assist small farmers and other small businesses and individuals whose livelihood is impacted by extremes in precipitation. We created a suite of resources, some of which will be found in this lesson, that you can look over to learn more about how and why we use NASA data to improve Earth's environment and have a positive impact of people around the world.

Materials:

Engage-

For the whole class-

- Plastic world globe
- Clear plastic cup
- Water in a larger container to pour into the cup
- Eyedropper/pipette

"Water for Wheaties?" PowerPoint presentation

Explore:

"Water for Wheaties?" PowerPoint presentation

Explain:

"Water for Wheaties?" PowerPoint presentation
GPM Precipitation Data to Compare/Contrast resource sheet to use in Project Teams

Copies of the Expert Group resource sheets below for each member of the "Expert Group". It will work best if students have access to these documents online with internet connectivity as there are some hyperlinks which lead to short videos in some Expert resource sheets. If this is not available, perhaps the students can watch the short videos on a computer.

"Expert Group" Student Resource Sheets-

- Growing Wheat
- Weather and Climate in Sargodha, Pakistan
- Weather and Climate in Gypsum, Kansas

- Pakistan Freshwater Availability

- Note-Taking Organizer (for each student to use in Expert Group)

Optional: a print copy of Interview with Faisal Hossain (You may decide to have students read this on the projector as a group, or have each student have their own copy.)

Evaluate:
"Water for Wheaties?" PowerPoint presentation

Water for Wheaties rubric: one copy for each student or small group (Teacher can decide if evaluation projects will be completed by individual students or in small groups.) The teacher should review the rubric and consider what types of projects (posters, PPT presentations, comics, skits, video product, etc. using a Universal Design for Learning approach)

Extend:
"Water for Wheaties?" PowerPoint presentation

Engage:
The purpose of the activities in this section are to begin to make students aware of the need for freshwater resources for agriculture. They begin by brainstorming about the foods they eat which are grown by farmers, and then move into understanding that farmers need freshwater to grow crops and raise animals. They will review the process of photosynthesis as the cycling of matter into and out of plants by examining a diagram of the movement of this energy. They will also review the water cycle with an emphasis placed on the fact that the sun serves as the primary driver of energy for these processes to occur.

Key Focus: Farmers need water to grow crops. Plants use photosynthesis to convert the sun's energy into glucose, which they need to survive. The hydrologic cycle provides plants with the water they require.

Ask each student to make a list of the things that he/she had to eat yesterday. Tell them to put a star by the things that needed to be grown by farmers. Have them circle items on their lists which include ingredients that originally came from farms. (slide 2)

As a class, think about what farmers need to have in order to grow their crops. Make a class list of the different things that are essential to growing food to meet the needs of people around the world. (slide 3)

Discuss the needs of these crops to have both sun and water. Review the processes that are involved in "photosynthesis". (slide 4)

Show students the short water cycle animation (2:59- it has no narration) on slide 5. You will click on the picture to open the link that has the animation. You might want to download it ahead of time so it plays fluidly. Help them to name the different processes that are interacting as water moves through the water cycle. Have them identify the processes that include transpiration, evaporation, condensation, crystallization, and precipitation. Emphasize the ways that water changes its state as it moves through the multiple pathways of the hydrologic cycle.

Key Focus: Most of Earth's water is salt water. Less than 2.5% of Earth's water is freshwater. Describe and view graphs to understand the amounts and percentages of water and fresh water in various reservoirs on Earth. Farmers use freshwater resources to water their crops. Water is a natural resource that is not renewable. It is unequally distributed around the world.

Look at a globe and ask how much of Earth's surface is covered by water. Do the Globe activity to predict how much of Earth is covered by water. (slide 6)

Watch the video, "Show Me the Water"- 02:49 (slide 7) Click on the picture to open the link. You might want to upload the video ahead of time to ensure it plays smoothly.

Use the bar graph on slide 8 to help students unpack the concepts of where the Earth's water is located. Ensure that they understand how little of Earth's water is actually freshwater. Help them identify the possible water sources on these bar graphs that would be used by farmers to water their crops. Examples of this would include groundwater if they use wells, surface water, atmospheric water (precipitation), rivers, and lakes.

Discuss the questions on slide 9 to help frame students' understanding about the usage of freshwater resources by farmers around the world. Guide students to compare and contrast how much water is used by developing countries and the U.S. for agriculture usage (developing countries- about 70% compared to US about 31 %) as well as the difference between irrigating crops and allowing precipitation to water them. This will be reinforced later as well.

Read the article, "Precious Freshness" and use the information to answer the questions as a class on slide 10. The class can read this article as a class or students can have paper copies (or read electronically on their own).

Explore:
Now the students will begin to think more specifically about the ways in which freshwater resources are used around the world. They will begin to learn about wheat and its importance in our diet. Before they begin their "Expert Group" research, they will also learn the difference between having precipitation water crops and needing to irrigate the crops when there isn't adequate precipitation.

Key Focus: Watering crops by irrigating versus having them watered by precipitation

Help guide the students to understand the difference between having crops irrigated versus having enough precipitation to water them adequately. (slide 11)

Key Focus: Energy from the sun is used to create the energy that is found in wheat crops. That energy is then transferred to us when we eat wheat products.

Have students think about the many foods they eat that include wheat on slide 12. Ask them to consider what they know about growing wheat to help get them thinking about how and where wheat crops are grown. Allow them to share some of their background experiences with growing wheat.

Explain:
Now the students have some common background information and are ready to start working in their "Expert Groups". Divide the class into four small groups, each of whom will be responsible for becoming experts on one of these topics. It will work best if they have digital access to the resources below as there are many embedded hyperlinks. Some of these hyperlinks have video files.

- Growing Wheat
- Weather and Climate in Sargodha, Pakistan
- Weather and Climate in Gypsum, Kansas
- Pakistan Freshwater Availability

Have each student take notes on the Note-Taking Organizer to help them have notes to refer to when they get together in their Project Team. Each Project Team will consist of an expert from each group- and thus will be composed of 4 students.

A copy of the GPM Precipitation Data to Compare/Contrast for each Project Team (This will be much more meaningful if it can be printed in color. One for the team of four should be fine)

Key Focus: Understand the purpose of the Expert Groups and Project Teams

Explain to the students that they will work in smaller "Expert Groups" in order to become knowledgeable about one topic. This is how scientists and engineers work when they are working collaboratively on a project. They have different areas of expertise and get together in their "working groups" to build their common knowledge. (slide 13)

For this activity, they will focus on two different wheat growing regions in the world. One of these is in Kansas and the other is in Pakistan, which is a developing country. (slide 14)

After they work with their Expert Group and take notes and discuss their topic, they will assemble into different Project Teams. (slide 15)

Students will review the questions that they will be focusing on within each expert group to get a feel for the broader picture. (slide 16)

Key Focus: NASA has a satellite mission that measures global precipitation.

The Global Precipitation Measurement (GPM) mission is a NASA satellite mission that is able to measure the precipitation as it falls from the clouds to the ground. (slide 17)

Have students learn about this mission by watching "For Good Measure"- 02:01 Clicking on the image will open the link that has the video. The video is 2 minutes long, and will play more smoothly if you have it open and ready to go or download it ahead of time. (slide 18)

Key Focus: Unpacking data from GPM to answer questions in Project Teams

Give the students the directions for what they will do when they break into "Project Teams". These will be small teams of 4, which will include an expert from the different teams in order to be able to share their collective expertise as they attempt to answer a few key questions while looking at GPM data. (slide 19)

Take a minute to review the two locations that they will be looking at GPM's precipitation data to try to determine whether there is enough precipitation to water the wheat crops during each location's wheat growing season, or if they will also need to use irrigation methods. (slide 20)

The data that students are looking at is what is known as "IMERG" data. IMERG data is composed of precipitation estimates from combining microwave data from the

GMI, TMI, and other partner instruments. You can learn more about this data here, but the students may simply need to know that this is data that has been collected from the GPM mission. If you should want to find the IMERG monthly data for your school location, you can follow the directions here and obtain that data. That might be an interesting activity to do with the class after they have looked at the IMERG data for the two locations we are working with in this lesson.

Key Focus: Earth-observing satellites use remote sensing to gather data.

Ask them to think about how satellites are able to measure things like the amount of precipitation falling from the clouds. Let them suggest their ideas, and then show them slide 21 to offer them an example of something they use regularly that uses remote sensing.

Show them the short video (2:39) on slide 22 entitled "Getting the Big Picture" to help them understand how we are able to collect remotely sensed data from space to help us make measurements, or estimates, of Earth data. The video will play more smoothly if it is downloaded ahead of time.

Assign one member of each Expert Group to a Project Team, which will result in many small Project Teams with 4 members in each team. Allow them a few minutes to look over the data in their Project Team. Use the Graph Cube and question sheets from My NASA Data with your students to help them unpack what they are looking at with the interannual time series data graphs. If you have time, preparing the graph cubes ahead of time will enable students to interact with the graphs and help them to unpack the information in a more constructivist manner. There are accompanying student capture sheets that are scaffolded and thus ensure that all students can access the content (Universal Design for Learning). If time is a limitation, consider using gaming dice as an alternative or, for virtual instruction, consider using a free virtual gaming dice app found online.

After they have had enough time to begin to unpack the graphs, use slides 23 and 24 to ensure they are able to do the following:

- Understand that time is being shown on the x-axis using different colored lines. Each line represents a season- "DJF- December, January, February" and so on.
- Understand that the y-axis is showing how much precipitation was measured in *mm* per month (or estimated as it is using remotely sensed data).

Leave the questions on slide 25 and circulate to assist Project Teams as necessary.

They may find that using highlighters is helpful to figure out which data to look at for each location. For example, wheat growing season in Kansas (this information is in the Weather and Climate in Gypsum, Kansas resource) is fairly long. Wheat is planted in the fall, becomes dormant in the winter, and grows in the spring and is harvested in June and July. Thus, the growing season is longer, but the most water will be needed during the spring and early summer. The students could use their highlighters and find the lines that show MAM (March-April-May) as well as JJA (June-July-August). It will not be possible to be exact with this data, but they can be looking for patterns and trends in the data. They may also need some assistance in finding and highlighting the important information that they will need to help them answer their Project Team questions as they look through their Expert Group resources.

It is helpful to work as a class and create a data table to compare and contrast the approximate amount of precipitation that fell during the primate growing season-MAM. It could be generated on the blackboard or using a projector. Students might have their own copies or create their own data table to fill in the data as it is a good exercise in learning how to approximate data from a graph.

Here is an example: (I ran out of room, but you would add 2019 as well.)

Comparison of Precipitation totals in mm for March-April-May

year	2001	2002	2003	2004	2005	2006	2007	2008	2009
Sargodha	30	20	25	15	40	33	35	49	42
Gypsum	80	76	102	97	79	77	170	98	92

year	2010	2011	2012	2013	2014	2015	2016	2017	2018
Sargodha	13	22	26	41	72	102	70	40	42
Gypsum	86	70	58	98	47	102	118	126	56

They may also try to convert the mm units to cm units- easy enough with the metric system as they just divide by 10- to see if there is enough precipitation to grow wheat without needing to use other water to irrigate the wheat crops. (from the "Growing Wheat" resource- they will note that growing wheat requires between 31-38 cm of precipitation, which will be 310 -380 mm) This is not necessary, however, to understand that the farmers will need to irrigate their wheat crops dung the spring season when they do not receive much rain.

From time to time, you may want to use slides 23 and 24 to point out important information or have students assist others in interpreting the data.

Once students have had time to work in their Project Teams and you determine it is time to come together as a class and share in their answers, bring the class back

together to answer the questions on slide 25 together. Help them use argumentation strategies to come to a class consensus on the answers.

Key Focus- Using technology to reduce the amount of freshwater resources needed in Pakistan for growing wheat

Now students are ready to use what they have learned to consider some possible ways in which technologies could be used to solve a real-world problem, that of limited freshwater resources in Pakistan. Help them to begin this process by showing them slide 26 and having them brainstorm what is happening in this picture.

After they have thought about what was happening in the first picture, show them slide 27 as it will give them additional information to use to try to figure out how

Key Focus- Meet Faisal Hossain and learn about his STEM-related career

Faisal Hossain is a professor who teaches civil and environmental engineering at the University of Washington in Washington state. He uses the data from GPM and other NASA satellite missions to help wheat farmers in Pakistan. The farmers get text messages every day letting them know whether or not they should water their wheat crops. He will introduce himself in a short video (02:48) on slide 28.

Slide 29 includes a quote from Faisal Hossain about the work he is doing with NASA data. After the students have had this chance to get a little background information about him and his work, have students read about his work in the resource, Interview with Faisal Hossain on slide 30. You can show this document on the large screen and/or have each student have their own printed copy.

As students read the interview, have them use the questions on slide 31 to guide their reading. When they finish, use the diagram on slide 32 to help students see the model that is being used by Faisal Hossain in his work with wheat farmers.

Show them the video on slide 33 entitled "Guiding Farmers with NASA Satellites", (4:04). This video reviews what they have learned and explains the complex reasons for the shortage of freshwater resources in Pakistan. Faisal Hossain is featured as he describes how he NASA and other data to assist farmers in using their cell phones to receive messages so they can irrigate less and rely on using precipitation when possible.

Here are some resources to learn more about the work Faisal is doing to reduce the use of freshwater resources using technology. Some of the content might be too

complex for middle school students, but you might find portions of this information useful for yourself and your students.

- Growing More with Less: Smart Tech Solutions to Feed the World (video presentation by Faisal Hossain)
- Professor Faisal Hossain modernizes irrigation to feed the masses (article from The Daily with many links to more information)
- A collection of videos by Faisal Hossain

Evaluate:

Key Focus: Understand that most careers require us to communicate our findings to others. This is true for scientists and engineers as well.

Help students to understand that most careers require that people have a way to communicate what they learn to others. This is true for scientists and engineers as well. Use slide 34 to review the scientific research process and see where "Present Findings" falls within the scientific research process.

Key Focus: Understand the expectations for the project

Use slide 35 to frame the expectations for the content the students will include in their final project. This could be completed as an in class or homework assignment. Based on the needs of your students and your classroom environment, you can determine whether the projects will be completed individually or in small groups. The rubric is based on a final product being a brochure, and includes assessment in these areas: writing- ideas, writing- sentence fluency, Media- graphics, Design- layout and organization, Planning- rough draft. The teacher may of course modify this rubric to meet the unique needs of their learners as well as to reflect the types of presentations that work for their learners.

Elaborate/Extend:

Key Focus- Using technology to access GPM data for your backyard

Slide 36- By following the fairly easy directions, students can use the "From Satellites to Your Backyard" online interactive to access the precipitation data for almost any location in the world. This could be given as a homework assignment if students have internet connectivity at home.

Key Focus- NASA Earth observing missions help us understand our home planet

Click on the image on slide 37 to open the link that has a short video entitled "Why Does NASA Study Earth?". This video is very short (1:52) and uses drawings to explain why and how NASA Earth observing satellites help us learn about Earth.

Key Focus: Saving Freshwater Resources
Slide 38 has a link to the EPA's "WaterSense" website with activities and information for students and teachers.

Show students slide 39 and have them brainstorm on the question.
Have them read "Earth's Water Delivery:? No Passport Required" to learn more about Earth's freshwater resources and how they are inequitably distributed around the world. Students could have their own copies or read the article as a class on the projector screen.

Key Focus: Using GPM data to assist small farmers and businesses to obtain low-cost insurance. STEM careers also include those who plan and offer insurance policies.

An interesting addition to this lesson would be to have students learn about how GPM data is being used to also assist small farmers and other small business owners to afford micro-insurance. Unexpected shocks from natural hazards can affect populations throughout the globe, threatening sustainable development and resilience. However, the impacts of these events such as extreme precipitation or drought disproportionately affects the developing world where individuals often are not insured and live and work in conditions that leave them vulnerable to natural disasters. This can lead to significant economic and environmental challenges if preventive measures or mitigating measures are not taken in time. To reduce risks from natural disasters and build climate resilience, decision makers are using NASA Earth observations to develop index-based insurance products and protect low-income customers in Central America.

An example of this is a company called MiCRO. The Microinsurance Catastrophe Risk Organization (MiCRO) is a reinsurer that specializes in design and implementation of innovative, holistic, affordable and sustainable risk management solutions against natural disasters for the most vulnerable populations. MiCRO's approach is based on a technology platform that provide risk management solutions to deliver tailor-made insurance policies. These policies are designed to protect vulnerable individuals (e.g. subsistence farmers) and small and micro-entrepreneurs against various perils such as excessive rainfall, severe drought, and earthquakes using a pre-determined index (e.g. threshold) that is correlated to direct and indirect losses in a given region. These indices such a precipitation can be monitored using NASA satellites and provide cost-effective and efficient way to capture weather-related parameters like droughts, especially where ground data is sparse. Access to historical and real-time data, such as precipitation data from NASA GPM, has

enabled MiCRO to create their index in order to approximate actual damages and issue claim payouts when precipitation (or other extreme weather events) falls above or below the corresponding threshold in a given region.

This topic can be introduced to students using the questions on slide 40. After they have contemplated the reasons for farmers to have insurance, they can review the information about microinsurance on slide 41. They will continue to slide 42 to gain additional information about why GPM data can be used for this purpose.

Slide 43, contains a video "*NASA Satellites Help Farmers in Central America's Dry Corridor*" (02:46) explains how unexpected shocks from natural hazards can affect populations throughout the globe, threatening sustainable development and resilience. However, the impacts of these events, such as extreme precipitation or drought, disproportionately affect the developing world where individuals often are not insured and live and work in conditions that leave them vulnerable to natural disasters. This can lead to significant economic and environmental challenges if preventive measures or mitigating measures are not taken in time. To reduce risks from natural disasters and build climate resilience, decision makers are using NASA Earth observations to develop index-based insurance products and protect low-income customers in Central America, especially in the region known as the Dry Corridor. The video is available in both English and Spanish.

Slide 44 gives a visual model of the process of using NASA Earth observations to help those who are most vulnerable to the negative impacts of natural disasters.

There is a short video that can be accessed on slide 45 along with a quote and a little more information about Iker Llabres and the work he does in his STEM-related profession. Slide 46 has a little more information about Iker and a link to the Interview with Iker Llabres. This could be read as a whole class on the projector screen or read individually/in small groups.

Additional Resources:
There are more resources you and the students might want to explore on slide 47and slide 48. You may also want to explore the resources in GPM's "Precipitation Education" website, as there are a rich array of educational resources on this website.

Students can explore climate classification systems using this GLOBE "What is Your Climate Classification?" activity.

The Smithsonian has a fantastic curriculum entitled *Food!* This is a freely available community research guide developed by the Smithsonian Science Education Center

(SSEC) in partnership with the InterAcademy Partnership as part of the Smithsonian Science for Global Goals project. These Smithsonian Science for Global Goals community research guides use the United Nations Sustainable Development Goals (SDGs) as a framework to focus on sustainable actions that are defined and implemented by students.

Credits:
Special thanks to Faisal Hossain and the "Pakistan Council of Research in Water Resources" (http://www.pcrwr.gov.pk) for contributing to this work as well as to Iker Llabres and the MiCRO organization.