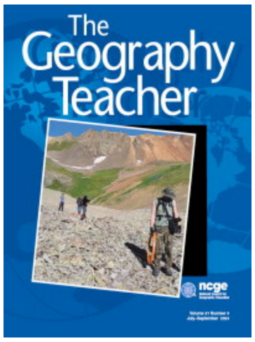

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LESSON PLAN

Analyzing the Effect of Impervious Surfaces on Flooding

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This lesson incorporates ArcGIS Online (AGOL) visualization in an assessment of sunny-day flooding. Students consider how land use and landcover play a role in flood risk. Flood days have increased across many coastal and non-coastal landscapes (Hoffman et al. 2023; Allen and Allen 2019; Garner et al. 2023). Increases in heavy rain events are a result of anthropogenic climate change (USGCRP 2023). In this activity, students are asked not only to assess how impervious areas modify hydrology but also to brainstorm ideas about how to improve land use in their local community, thereby reducing flood risk. Learners may expand their knowledge as to the role of green infrastructure in flood-mitigation efforts and how heat-trapping gases play a role in increasing flood risk. Green infrastructure also provides habitat and sequesters these heat-trapping gases.

Target Audience

- Middle or high school students in an honors-level or advanced science class with moderate to advanced technological capabilities. Students will need to have access to a computer and AGOL. Many free resources and training webinars exist through Esri, Inc (2024a).

Learning Objectives

- Students will use ArcGIS Online to analyze impervious land cover.
- Students will calculate impervious surfaces using ArcGIS map layers and visually compare and/or mathematically calculate impervious surfaces and compare across places.
- Students will brainstorm design ideas to help reduce impervious surfaces in their community.
- Students will explore how impervious surfaces modify flooding risk in a changing climate.

Key Terms

- An **impervious surface** is a surface that does not allow rainfall to penetrate, often causing runoff.
- A **pervious surface** is a surface that allows rainfall or water to penetrate, limiting runoff, and may be ecologically advantageous.

Educational Guide

This lesson includes seven parts and may be divided into multiple class periods and days.

Part I. Asking Questions (30 Minutes)

- Students will sort a variety of cards depicting various types of land cover into a minimum of two groups (Figure 1).
- Once students have sorted the cards, students should discuss with the class why or how they chose to sort their cards. Student answers will vary.
- Teachers will demonstrate how they would sort the cards into the groups, drawing the distinction between pervious and impervious land-cover types.
- The teacher either re-teaches the concepts of impervious surfaces or introduces the vocabulary words and concepts.

Part II. Comparing Places (15 Minutes)

- On whiteboards or sticky notes, have students answer the following question: What contributes to flooding? Student answers will vary.
- Highlight student answers that deal with asphalt, parking lots, or standing water in human-constructed areas.
- Following the discussion of student answers, show the video below:
    - o Carrington (2021) Climate change is making floods worse: here's how, *Guardian News* https://www.youtube.com/watch?v=fbyK1z1_W4s
- Explain that humanmade or impervious surfaces only further the climate change–driven increase in global flooding.

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Figure 1. Land-use cards (Bellington Water School 2022).

Part III. Investigating (60 Minutes)

- Break students into groups to read articles in a jigsaw style (Center for Research on Teaching and Learning 2024).
  - Vogelsong (2021). Yes, Virginia, we are seeing more—and more intense—rainfall, Virginia Mercury. https://www.virginiamercury.com/2021/08/20/yes-virginia-we-are-seeing-more-and-more-intense-rainfall/
  - Scientific Inquirer (Collins 2022). The dangers of urban flooding are increased by concrete, asphalt, and brick. https://scientificinquirer.com/2021/07/22/the-dangers-of-urban-flooding-are-increased-by-concrete-asphalt-and-brick/
  - Johnson (2022). Students identify Chicago neighborhoods most at risk of urban flooding, UChicago News, https://news.uchicago.edu/story/students-identify-chicago-neighborhoods-most-risk-urban-flooding
  - Schwartz (2018). More floods and more droughts: climate change delivers both. New York Times, https://www.nytimes.com/2018/12/12/climate/climate-change-floods-droughts.html
- Have students share a paragraph summary of their article. Students may summarize using bullet points or build connections from prior classes.
- Research and provide materials to discuss any recent natural disasters that involve floods, such as Hurricane Helene in the fall of 2024.
  - Bartles (2024). Why Appalachia flooded so severely from Helene's remnants. Scientific American. September 30, 2024. https://www.scientificamerican.com/article/why-appalachia-flooded-so-severely-from-helenes-remnants/
  - Davis (2024). Rapid reaction: historic flooding follows Helene in Western NC. Climate blog. North Carolina State Climate Office. September 30, 2024. https://climate.ncsu.edu/blog/2024/09/rapid-reaction-historic-flooding-follows-helene-in-western-nc/
  - Deem (2024). Helene shows growing reach of hurricanes well into Georgia and beyond, experts say. Savanah Morning News. October 2, 2024. https://www.savannahnow.com/story/news/climate-change/2024/10/02/helenes-impact-on-georgia-an-example-of-climate-change-influence/75473707007/
- The key takeaway: Climate change makes extreme weather events such as flooding increase in frequency.

Part IV. Exploring and Visualizing (30 Minutes)

- Ask students what the key elements of a map are. Students should identify concepts such as title, date, legend/key, color, scale, and compass (Ekiss 2023). Discuss the importance of a legend.
- Give students a few minutes to explore the Chesapeake Bay watershed land cover data from the Chesapeake Conservancy (2023). Clicking the LULC Viewer allows students to zoom in on their own region of interest (Figure 2). Students may discuss different datasets, when they were created, and how the patterns may change through time or with improved resolution, as described in the article below.
  - Chesapeake Conservancy (2023). CBP Land Use/Land Cover Data Project, https://www.chesapeakeconservancy.org/conservation-innovation-center/high-resolution-data/lulc-data-project-2022/
- Open ArcGIS Online: www.arcgis.com. Sign in using your credentials.

Note: If you are uncertain as to whether or not your school or district has a free AGOL account, talk with your information technology software team or school leader (Esri 2023). Many districts have invested in such technology and may offer technical training (Esri 2024c). Esri, Inc. (2024b) also provides support and resources.

  - Navigate to "Map" on the top toolbar. This will open an untitled map. You may opt to rename and save your map.
  - Open in Map View Classic (top right).
  - Click "Add" and then "Browse Living Atlas Layers."

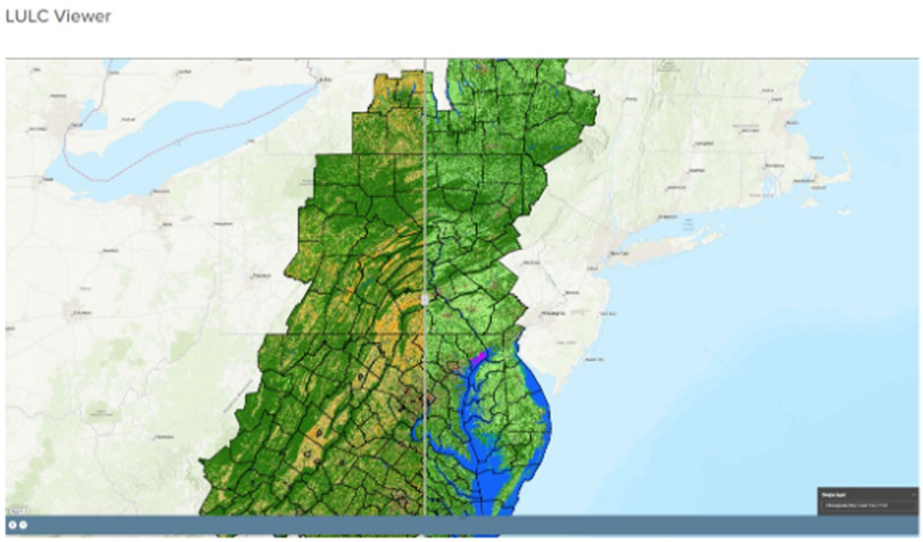

Figure 2. Chesapeake Bay watershed Land Use Land Cover (LULC) Viewer from the Chesapeake Conservancy (2023).

- o Search for the layer "Sentinel-2 10m land use/land cover time series of the world." This authoritative dataset originates from ESRI_Imagery and was first created in October 2022 (Figure 3).
- Discuss with students to exclude "no data" in subsequent activities. Explain the similarities and differences between Land Use and Land Cover. Legends differentiate pervious and impervious surfaces. Discuss the issue of scale (National Geographic Education 2024). Large-scale maps offer more detail and cover smaller areas, such as a school campus or county. Small-scale maps cover a larger area and provide different points for comparison. Resolution and detail will vary accordingly.
  - o Land Cover represents the surface characteristics of the land with classes such as impervious cover, tree canopy, herbaceous, and barren.
  - o Land Use represents how humans use and manage the land, with classes such as turf grass, cropland, and timber harvest.
- Practice understanding how scale affects map interpretation by incorporating the Esri GeoInquiry on "Distance and Scale" from the Human Geography collection (https://www.esri.com/en-us/industries/k-12-education/geoinquiries/human-geography) (Figure 4).

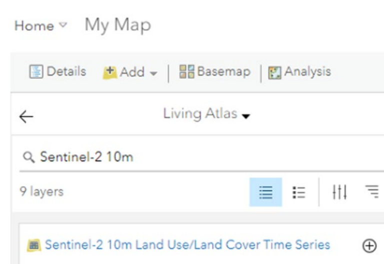

Figure 3. ArcGIS Online portal.

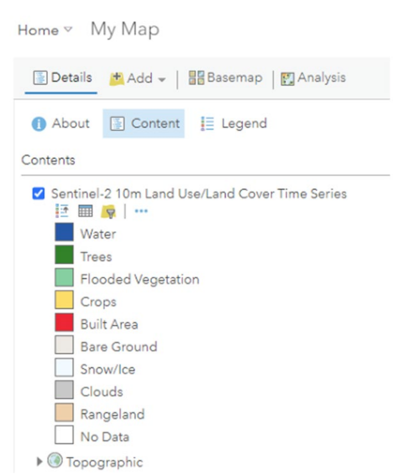

Figure 4. Content manager outlines dataset and basemap.

Part V. Conducting Geospatial Analysis (60 Minutes)

- Depending on the independence or technological capabilities of your students, the following can be done as a class to demonstrate the tools:
  - o Students can use the measurement tool on ArcGIS Online or ArcGIS Pro to calculate the square meter areas of the impervious or pervious surfaces in their local community. For practice using the measurement tool, explore the D = R*T GeoInquiry exercise (https://www.esri.com/content/dam/esrisites/en-us/media/pdf/geoinquiries/math/2-drt-math-geoinquiry.pdf).
  - o Students can record the square meter area they find on their student worksheet for both pervious and impervious surfaces, discussing data limitations and the issue of resolution.
- Students will follow through guided questions to figure out how much impervious areas surround a landmark of their choosing. Make this pertinent to your area; for example, do not select the Eiffel Tower.

Table 1. Evaluation rubric.

Criteria	Excellent (3)	Good (2)	Needs Improvement (1)
Analysis Techniques	Uses advanced GIS techniques effectively; analysis is thorough.	Uses standard techniques correctly; analysis is solid.	Lacks appropriate techniques; analysis is flawed.
Interpretation	Results are well justified and insightful; connects back to objectives.	Results are mostly justified; some connections to objectives.	Results are poorly interpreted; no clear connection to objectives.
Storytelling and Communication	Presentation is visually appealing and well organized; uses appropriate maps and visuals.	Presentation is clear and mostly organized; some visuals used effectively.	Presentation is unclear and poorly organized; lacks effective visuals.
Critical Thinking	Shows exceptional critical thinking and problem-solving skills throughout the project.	Demonstrates good critical thinking; some areas need deeper analysis.	Minimal critical thinking evident; relies heavily on surface-level analysis.
Collaboration and Teamwork (if applicable)	Worked exceptionally well with others; contributions were clear and impactful.	Demonstrates good critical thinking; some areas need deeper analysis.	Poor collaboration; did not contribute effectively.

- Students may elect to measure their house or neighborhood for impervious surfaces.
- As students are analyzing the land cover, they should brainstorm ideas that may limit the urban heat island or reduce flooding on their map site.

Part VI. Telling the Story (60 Minutes)

- Students will communicate their findings, perhaps by generating an ArcGIS StoryMap that includes the following:
  - o Description of flooding and an example of how increased flooding is a climate change issue.
  - o Description and example of impervious vs. pervious surface types in their own words.
  - o Map that shows the school building and location of choice.
  - o Math techniques used to calculate previous vs. impervious land areas.
  - o Discussion of data limitations and the importance of resolution.
- Need an example of what a StoryMap looks like? Check out these resources:
  - o University of Richmond (2020). Lines than shape our cities, Digital Scholarship Lab, ArcGIS StoryMap https://storymaps.arcgis.com/stories/0f58d49c566b486482b3e64e9e5f7ac9
  - o Esri, Inc (2021). How to make a StoryMap, https://storymaps-classic.arcgis.com/en/how-to
  - o Esri Ireland (2020). How to create an ArcGIS StoryMap in under 10 minutes, https://www.youtube.com/watch?v=aVPUQTRrdfU

Part VII. Reviewing Actions, Solutions, and Reflections

- Students will brainstorm ways to improve impervious areas near their chosen location. This will be the final component of their StoryMap.
- Students can discuss intersectional issues such as the urban heat island, emergency management, transportation, demographics, or economy.
- Educators may have students summarize main concepts and evaluate learning (Table 1).

Extension Options

Students use ArcGIS Pro to calculate the percentage of land coverage for each type in their original location of choice.

Students develop a petition for the community to change various land coverage, such as adding rain gardens next to parking lots or school properties.

Students may utilize the National Geographic MapMaker (2024) to explore additional datasets, linking the environment and human systems.

Disclosure Statement

No potential conflict of interest was reported by the author(s).

Notes on Contributors

Lydia Belser is a Google-Certified Educator and National Science Foundation Robert Noyce Scholar. With more than 5 years of teaching experience in formal and informal K–12 education settings, Lydia works to further high-quality teaching in underserved areas. She most recently taught oceanography and environmental science at James River High School in Chesterfield County, Virginia. Lydia is a graduate of The College of William & Mary, with a BS in biology and marine science and an MA in Education with a specialization in curriculum and instruction in secondary science.

Michael J. Allen, PhD, is an Assistant Professor of Climatology within the Department of Geography and Environmental Planning at Towson University. He previously served as co-coordinator of the Virginia Geographic Alliance and as Geography Program Director at Old Dominion University. In addition to having interests in geographic literacy and climate education, Dr. Allen explores the intersection of weather, climate, and human health. In 2023, he was a U.S. Fulbright Scholar in Serbia.

Jamie Young is a National Geographic-Certified Educator and Geo-Inquiry Ambassador and has more than 20 years of teaching experience in public schools/college. She taught Earth Science for 19 years, and she exposed her students to experiential, place-based learning. She is presently a STEAM educator at Old Donation School in Virginia Beach, Virginia. She integrates climate issues into her coding and engineering design activities. An active member of the Virginia Geographic Alliance, Jamie has both a BS in Criminal Justice and Political Science and a master's degree in Education.

Anna Simon is presently a Geologist II at AECOM in Virginia Beach, Virginia. She previously was a science educator at Renaissance Academy in Virginia Beach, Virginia, for five years. As an alternative education teacher, Anna exposed her students to the community around them through local field trips and scientific inquiry. Anna earned a BS in Geology from Marshall University and a master's degree in Oceanography from the University of Rhode Island.

Shelly Carter, an elementary school educator for more than 10 years, currently teaches preschool in Rockbridge County, Virginia. With a passion for social emotional learning and integrating students' well-being with all academic learning, she incorporates outdoor learning experiences into her curriculum. Shelly earned both a BBA and MAT from James Madison University.

Michele Sullivan incorporates aspects of the natural world into her lessons and emphasizes outdoor learning. For more than 10 years, Michele has been a fifth-grade teacher with Fairfax County Public Schools. As an Eco Teams Leader for Mantua Elementary School, Michele works with students to plant trees on campus and install native, pollinator species in bioretention facilities. Michele earned a BA in Quantitative Economics from Stanford University and an MBA from the University of Virginia's Darden School of Business.

Gretchen Maxwell is an Advanced Academic Resource Teacher in Fairfax County, Virginia. A career switcher, she wanted to implement change by encouraging and advocating for the students in her neighborhood Title 1 school, Westlawn Elementary. She is the daughter, sister, and mother of scientists and loves nothing more than using different pathways to expose students to new experiences outside. Gretchen earned her MS in gifted education from Arkansas State University.

Gabrielle Hurst is a K–6 Gifted Resource Educator in the Virginia Beach City Public School System and Virginia Master Naturalist. These experiences help her incorporate citizen science activities into the classroom. For the last 15 years, her experience includes providing classroom instruction for third and fifth grade and working as a sixth-grade Advanced Life Science teacher and a Gifted Resource teacher assisting grades K–5. She also oversees school garden projects and helps students learn about organic growing, composting, and sustainable acts. Gabrielle earned a BBA in accounting and an MS in Education from Old Dominion University.

Jennifer L. Whytlaw, PhD, GISP, is an Assistant Professor of Applied GIS in the Department of Political Science and Geography at Old Dominion University. Her research focuses on utilizing geospatial analyses and visualizations to understand how environmental hazard events influence personal understanding of vulnerabilities within communities.

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