The Environmental Impacts of Urbanization and Land Use Changes in Delaware

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Introduction and Rationale

Maps have always been a personal source of wonder for me. From basic relief maps of the United States to interactive maps of the most recent earthquakes and volcanic eruptions, I have probably spent entirely too long staring at maps in a state of awe, deep in thought about what I am seeing. To me a good map is like a piece of artwork in that it has many different levels and is open to interpretation based on the viewer's background, and the best ones are often aesthetically pleasing enough to be framed and hung in museums. But their value obviously lies in their ability to communicate place-based data in a way that tables and numbers simply cannot. Through this unit designed for AP Environmental Science I hope to develop students' geographic interpretation and analytical skills by focusing on the phenomenon of urbanization and land use change and their environmental impacts in the state of Delaware, with a specific focus on the impacts of increase in impervious surfaces and urban heat islands.

William Penn High School is a public high school in the Colonial School District in New Castle County, DE. It is the only high school in the district and is the largest high school in the entire state, serving between 2,000 and 2,200 each year across grades 9-12. The district is considered suburban/urban fringe and serves a diverse population in terms of both race and income. Several years ago, William Penn began focusing on the growth of Career and Technical Education (CTE) programs that provide opportunities for students to experience a vocational-type education while still being provided with the traditional college preparatory education typical of public schools. Such a shift has allowed the school to retain students who may otherwise attend one of the four area Vo-Tech schools. Students entering William Penn chose a degree program to specialize within one of three college academies: Business, Humanities, or STEM. Degree programs within the Business College Academy include Air Force JRTOC, Business Administration, Culinary Arts, Financial Services, and Accounting. Degree programs with the Humanities College Academy include Behavioral Sciences, Communications, Teacher Academy, Legal Studies, International Studies, and Visual and Performing Arts. The STEM College Academy offers degree programs in Agriculture, Allied Health, Computer Science, Construction, Engineering, Manufacturing, Mathematics, and Science. William Penn also offers 25 Advanced Placement courses, the largest number of any school in the state. This dual focus on college and career readiness has greatly improved the school culture and the school's image in the community, which has translated to the growth in the student population.

This growth in student population and interest in the sciences helped me justify the need for adding APES to the course catalog in the 2016/17 school year. Students enrolled in the Agriculture degree program can specialize in the Environmental Science pathway, which requires them to take two years of on-level environmental science before enrolling in APES as their capstone course. Since the course is officially part of a CTE program, students are expected to finish the course with some sort of job-applicable skill. To me, getting students to think critically about environmental problems and potential solutions is my primary goal, but am always looking for ways to address those job skills as well. And for anyone planning on becoming an environmental scientist or scientist in a related field, reading and interpreting maps is an incredibly important skill.

Content Objectives

This unit serves as an introduction to the concepts of urbanization, land use change, impervious surfaces, and the urban heat island effect. Students learn about the basics of each concept before focusing on their negative environmental consequences. After completing this unit, students are able to describe urbanization and land use change and explain how they have changed throughout human history. Students are also able to identify and describe the environmental impacts of increased impervious surfaces. Students are able to explain the connection between land use and the urban heat island effect. Finally, students are able to interpret geospatial information in the form of maps and data sets to explain how these concepts are related.

Urbanization

Urbanization is defined as the change in demographics, land cover, and economic process and characteristics of a geographic area associated with the movement of people and resources into higher density urban areas.[1] This process creates human-dominated landscapes that drive local and regional environmental changes, including changes in land cover, hydrological systems, and biogeochemistry. And though from a land area perspective it represents only a small form of land transformation, it has an outsize impact on the local environment,[2] acting as a primary driver of habitat loss,

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[1] Seto, Karen C., Roberto Sánchez-Rodríguez, and Michail Fragkias. 2010. "The New Geography of Contemporary Urbanization and the Environment." Annual Review of Environment and Resources 35 (November): 1

[2] Bounoua, Lahouari, and Joseph Nigro. 2018. "Mapping Urbanization in the United States from 2001 to 2011 - ScienceDirect." Applied Geography 90 (1). https://www.sciencedirect.com/science/article/pii/S0143622817302643?casa_token=OQR3V-COe3EAAAAA:1Y7LGybWh2W4elhUsmCG982qiJ4EVKmxVm4wwHxhTZuihbIdbnUHAWZOWN0DqXKaiQosAYqk91I.

fragmentation, and alteration, which is in turn a main driver of plant and animal species extinction.[3]

For most of human history, the majority of people lived in small, rural communities. However, in the past two centuries (and especially in recent decades) urbanization has brought more and more people from those isolated rural communities to urban and suburban areas, and by 2007, more people lived in urban areas than rural ones. As of 2017, more than 4.13 billion people lived in cities and their metropolitan regions, compared to 3.40 billion in rural communities. This trend is most pronounced in developed countries in the cultural "West."[4] In the United States, there are several areas of intense urbanization due to population growth such as Houston, TX and Phoenix, AZ, as well as several long-established urban areas such as the Northeast corridor that includes northern Delaware, which is the focus of this unit. This new wave of urbanization is also referred to as urban sprawl since most of the growth and development radiates outward from the traditional urban core to the less developed regions outside the city.

There are four main causes of the urban sprawl in the US that have characterized land use changes in recent decades that students should know: the advent of the automobile and the development of the interstate highway system; white flight and redlining; urban blight; and federal and local laws and policies such as zoning laws and government subsidized mortgages. Students should also be familiar with the major consequences of urban sprawl in the US, including the increase in fossil fuel use, increase in land use area per capita, and increased distance between farms and their eventual markets.[5]

Land Cover, Land Use, and Land Use Change

Land cover and land use are two terms that are often confused or taken to mean the same thing – however they do have two separate and distinct meanings. Land cover is the observed physical and biological cover of the earth's land, as vegetation or man-made features. Land use is defined as the total arrangement, activities, and inputs that people undertake in a certain type of land cover.[6] Their differences notwithstanding, land cover maps can still provide a basis for interpreting land use, as represented in Figure 1 below. It is important to note that changes in land use are not simply a modern issue; in fact,

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[3] Seto, Sánchez-Rodríguez, and Fragkias 2010
[4] Global Change Data Lab. 2020. "Urbanization - Our World in Data." Ourworldindata.Org. 2020. https://ourworldindata.org/urbanization.
[5] Friedland, Andrew, and Rick Relyea. 2019. Environmental Science for the AP Course. 3rd ed. New York: Bedford, Freeman, and Worth.
[6] IPCC. n.d. "Land Use, Land-Use Change and Forestry." Accessed October 10, 2020. https://www.grida.no/climate/ipcc/land_use/045.

large scale changes in land use began occurring with the development of agriculture some 10,000 years ago in various locations across the planet. The difference in land use change then and since the industrial revolution took hold is the scale and pace at which it has occurred. In early human times, changes to land and land use happened over long periods of time and space and even were the subject of reversal as empires rose and fell. But over the last few centuries, changes to land have become more dramatic in scale, rate, and permanence.[7] It should be noted that land use changes are not simply the result of urbanization, even though that is the focus of this unit. The shift in land use from natural vegetation (be it forest, grassland, etc.) to agriculture contributes greatly to land use changes, as does the conversion of land from natural vegetation to mining or other industrial operations. However, this unit focuses on the distinct relationships between urbanization, land use change, and their environmental impacts. Bloomberg released a cascade story map showing land use in the US in 2018.[8] This story map serves as an introduction to the topic for students.

Land Use Change in Delaware

Historically, northern Delaware was mostly forest,[9] with coastal wetlands bordering the Delaware River and its tributaries.[10] However, as demonstrated in Figure 1, almost all of this part of the state has been developed to some degree, as indicated by the high percentage of different shades of red. The urban core of the city of Wilmington is nearly all high intensity developed, and suburban sprawl can be seen as the high degree of medium intensity developed land surrounding the city. Some pockets of forest and cultivated land are still present, but mostly as islands amidst heavily developed land. The floodplain of the Christina River (pictured in light blue running diagonally in the center of the image) and coastline along the Delaware River are covered by woody or herbaceous wetlands, though their extent has been significantly reduced over the past century.[11]

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[7] Houghton, R. A. 1994. "The Worldwide Extent of Land-Use Change." BioScience 44 (5): 305–13. https://doi.org/10.2307/1312380.

[8] Merril, Dave, and Lauren Leatherby. 2018. "Here's How America Uses Its Land." 2018. https://www.bloomberg.com/graphics/2018-us-land-use/.

[9] Lister, Tonya W, Andrew J Lister, William H McWilliams, Randall S Morin, James A Westfall, Brett J Butler, Susan D Crocker, et al. 2017. "Delaware Forests." Newton Square, PA.

[10] Turner, Ralph W. 2001. "Delaware's Wetlands: Status and Recent Trends." Hadley, MA.

[11] Ibid

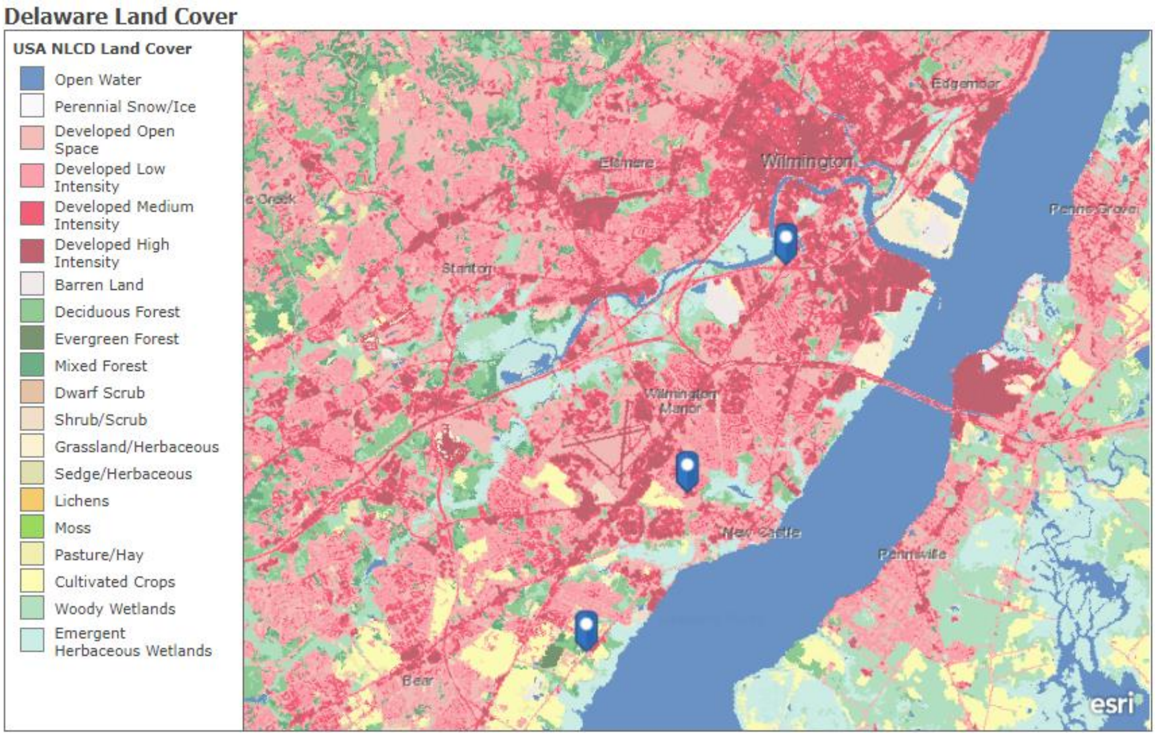

Figure 1: Land Cover in Northern Delaware Area, 2019.[12] Data provided by National Land Cover Database through Esri and ArcGIS.

In 1982, Delaware had roughly 135,000 acres of developed land. By 2007, this figure had almost doubled to 256,000 acres, which represents an increase of 90%. Because of this dramatic increase in development, nearly half of all the land that has been developed in Delaware was developed in the last 40 years.[13] During this same time period, cropland decreased by twenty percent and forest land decreased by nine percent.[14] This rapid conversion of land into urbanized areas has altered the Delaware landscape, especially south of already-developed northern New Castle County. Middletown, Smyrna, Lewes, and Bethany Beach are all hotspots for conversion of cropland or forest land into developed land.

Impervious Surfaces

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[12] Multi-Resolution Land Characteristics Consortium. 2019. "USA NCLD Land Cover." Esri. 2019. https://landscape10.arcgis.com/arcgis/rest/services/USA_NLCD_Land_Cover/ImageServer.

[13] "National Resources Inventory | NRCS Delaware." n.d. Accessed October 9, 2020. https://www.nrcs.usda.gov/wps/portal/nrcs/main/de/technical/dma/nri/.

[14] Ibid

Impervious surfaces are any materials that prevent the natural infiltration of water into the soil and groundwater. Examples include roads, rooftops, driveways, parking lots, and sidewalks.[15] The dominance of impervious surfaces in developed areas is a relatively recent development, emerging with the advent of the interstate highway system and the suburban sprawl it enabled. Under pre-development conditions, natural surfaces are able to absorb and infiltrate rainfall. But when they are developed and replaced with impervious surfaces, the local water cycle is dramatically impacted,[16] as depicted in Figure 2. The major impacts include reducing shallow and deep infiltration, reducing evapotranspiration, and significantly increasing the amount of surface water runoff. Additionally, local surface water bodies can be ecologically impaired, an impact that is discussed in more detail below.

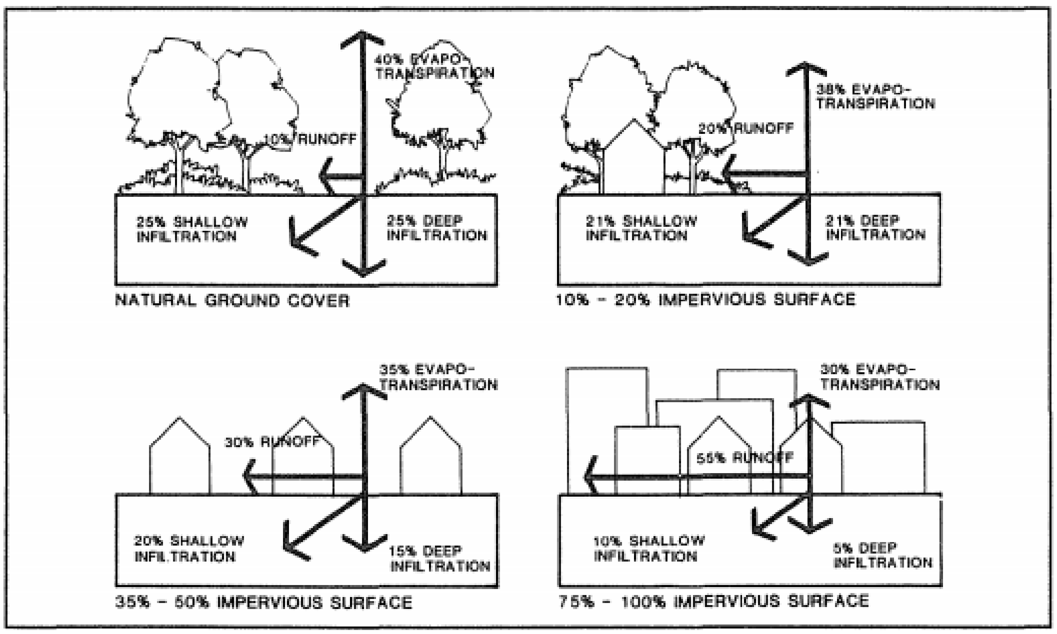

Figure 2: Water cycle changes associated with increased impervious surfaces due to urbanization.[17]

[15] Arnold, Chester L., and C. James Gibbons. 1996. "Impervious Surface Coverage: The Emergence of a Key Environmental Indicator." Journal of the American Planning Association 62 (2): 243–58. https://doi.org/10.1080/01944369608975688.
[16] Ibid
[17] US EPA. 1993. "Chapter 4: Management Measures for Urban Areas D." Guidance Specifying Management Measures for Sources of Nonpoint Source Pollution in Coastal Waters, no. January.

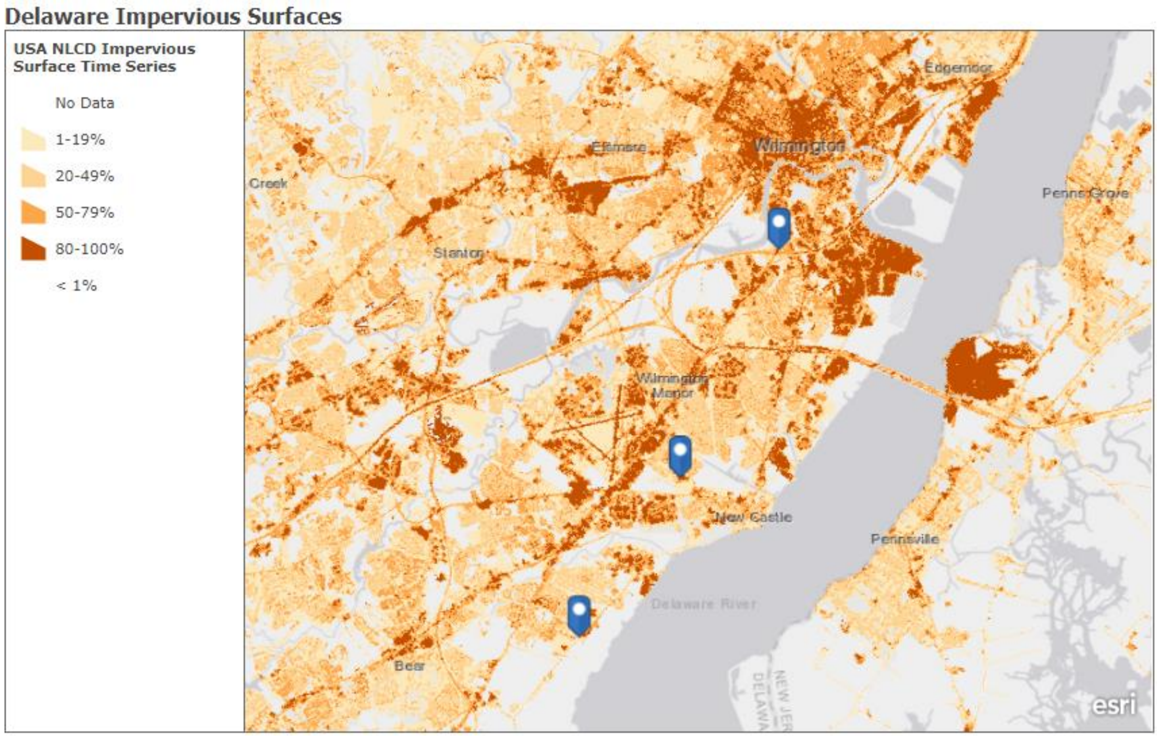

Figure 3: Impervious Surface Cover in the Greater New Castle, Delaware Area, 2014. Data provided by National Land Cover Database through Esri.[18]

The relationship between urbanization, land cover, and impervious surfaces is driven home by comparing Figures 1 and 3. The areas with the highest percentage of impervious surfaces are in the areas with the greatest amount of development. Major roadways can be seen as thin, interconnected strips of highly impervious surfaces, and major population centers or industrial areas are marked by spots of intense orange. Remaining areas of low impervious cover coincide partly with the "natural landscapes" bordering the Christina River and the coast of the Delaware River, as well as the limited forested and cultivated areas.

Environmental Impacts of Urbanization and Land Use Change

Urbanization has many negative environmental consequences. This unit addresses three specific impacts: increased stormwater runoff, degraded water quality, and the emergence of urban heat islands. Additional consequences not discussed in this unit include habitat loss, increased human-wildlife interactions, and urban sprawl and increased traffic congestion. The first two are not discussed because most of the land conversion is from cropland to urban land, so the initial habitat destruction was hundreds of years ago. Urban sprawl and increased traffic congestion are not discussed because of the many

[18] Multi-Resolution Land Characteristics Consortium 2019

contributing factors (especially Delaware's unique position between Philadelphia and Washington, D.C.).

Increased Stormwater Runoff

Stormwater is defined as the portion of precipitation that does not naturally percolate into the ground or evapotranspirate, but instead flows via overland flow, interflow, channels, or pipes, into a defined surface water channel or constructed infiltration facility such as a retention or detention pond.[19] In this unit, stormwater and stormwater runoff are used interchangeably. As discussed above, the impervious surfaces associated with urban and otherwise developed areas increase the total amount of increased stormwater runoff because less water can infiltrate and percolate through natural surfaces.

The rapid delivery of stormwater runoff to surface water bodies associated with high degrees of impervious surfaces is problematic for several reasons. These problems include routine localized flooding, erosion of stream banks, alteration of stream/river hydrology, and transfer of surface pollutants into local surface water bodies.[20] Routine flooding, erosion of stream banks, and alteration of stream/river hydrology have to do directly with the purpose of existing stormwater management techniques, which are designed to rapidly move water away from the built environment. In periods of heavy rain, this system can become quickly over-loaded, resulting in a backup of storm drains, which leads to localized flooding, especially in low-lying areas. Channeling stormwater from impervious surfaces into pipes greatly increases the velocity at which water enters streams, increasing its erosive potential and thus altering the stream/river hydrology. In areas where the stormwater and sewer systems are combined and routed to a treatment facility before discharge, an increase in stormwater flow can lead to a combined sewer overflow, where the volume of water is too great for the treatment facility and must be released untreated.[21] This has significant impacts on water quality, which is discussed in more detail below. In summary, the underground sewer systems so often employed to manage stormwater are problematic because they lead to the rapid release of polluted

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[19] National Research Council. 2009. Urban Stormwater Management in the United States. Urban Stormwater Management in the United States. Washington, D.C.: The National Academies Press. https://doi.org/10.17226/12465.

[20] Ibid

[21] Ibid

water into local surface waters,[22] excessive flows into local surface waters,[23] and backflow into streets and homes/businesses when the system is combined with sewage collection and overtaxed from a storm event.[24]

Degraded Water Quality

The transfer of surface pollutants into local surface water bodies is a substantial threat to stream, river, and pond/lake ecosystems: any pollutant on an impervious surface can potentially be washed away into a local creek or other water body during normal rain events. Such pollutants include oxygen depletors, pathogens, metals, nutrients, and still others that impact pH, turbidity, and total dissolved solids.[25] Oxygen depletors include ammonia and other constituents that increase the biochemical oxygen demand (BOD) of a water body, such as the organic compounds in sewage. Enteric pathogens can be released and are indicated by the presence of fecal coliform. Common metals in stormwater runoff include lead, mercury, and cadmium. Nitrogen and phosphorous are the primary nutrients carried by stormwater runoff and can cause eutrophication, a process that leads to oxygen and pH fluctuations and can lead to the release of toxins by blooming algae. Stormwater runoff can also directly impact the turbidity, and salinity or total dissolved solids in a surface water body.[26]

Urban Heat Islands

The urban heat island is a term used to describe the phenomenon where urban areas with a high degree of human infrastructure are warmer than their less developed surroundings.[27] This occurs because of several factors, including a reduction in natural landscapes in urban areas, properties of urban materials, urban geometry, human activities, and local weather and geography. The absence of natural landscapes in urban areas leads to increased temperatures because trees, vegetation, and bodies of water tend to cool the air by providing shade and through the cooling process of evapotranspiration.

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[22] Cettner, Annicka, Richard Ashley, Maria Viklander, and Kristina Nilsson. 2013. "Stormwater Management and Urban Planning: Lessons from 40 Years of Innovation." Journal of Environmental Planning and Management 56 (6): 786–801. https://doi.org/10.1080/09640568.2012.706216.

[23] Walsh, Christopher J., Tim D. Fletcher, and Matthew J. Burns. 2012. "Urban Stormwater Runoff: A New Class of Environmental Flow Problem." PLoS ONE 7 (9). https://doi.org/10.1371/journal.pone.0045814.

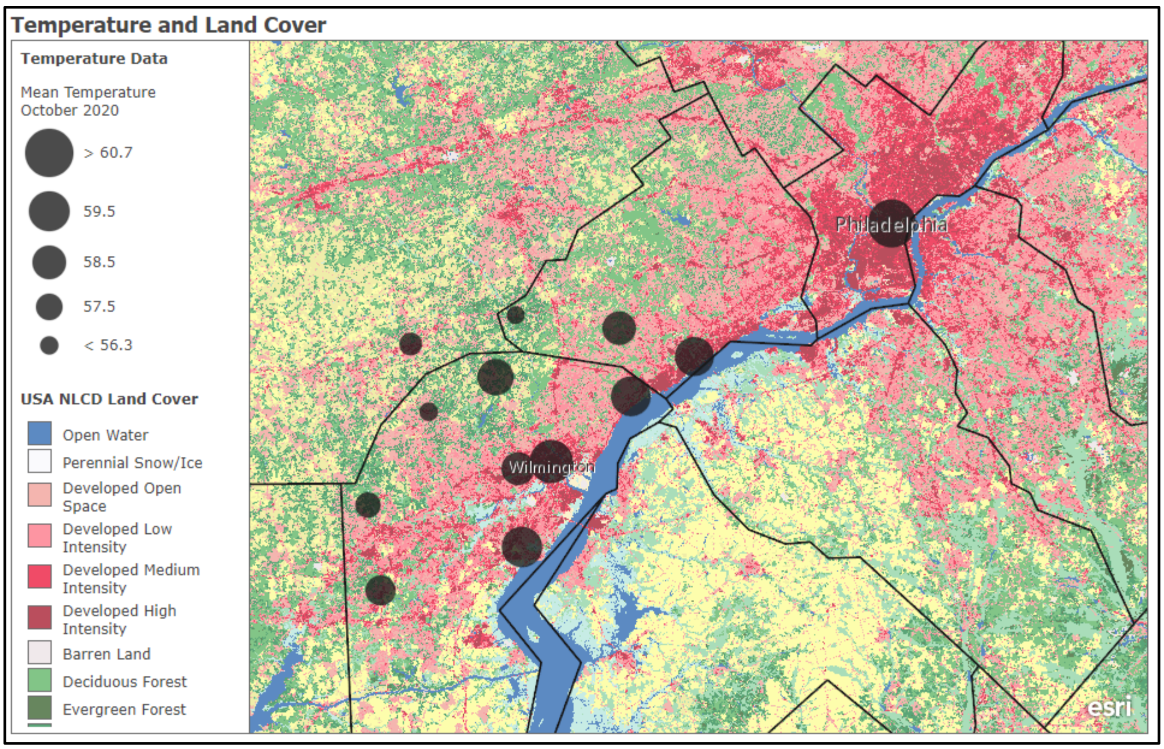
[24] Weber, Anna. 2019. "What Is Urban Flooding." NRDC.Org. 2019.

[25] National Research Council 2009

[26] Ibid

[27] US EPA. n.d. "Heat Island Impacts: Heat Island Effect" Accessed October 9, 2020. https://www.epa.gov/heatislands/heat-island-impacts.

In turn, surfaces such as roofs, sidewalks, roads, buildings, and parking lots provide less shade and moisture than natural landscapes. Such human features tend to reflect less solar energy and absorb and emit more heat energy compared to natural ones. These human features also tend to build up heat throughout the day and then slowly release it at night. The geometry of urban areas influence wind flow and alter urban materials' ability to absorb and release heat energy. Additionally, heat generated from human activities like driving, air-conditioning, and industrial facilities contributes to the heat island effect. Finally, specific geographic and weather conditions can amplify the effects of the urban heat island. Calm and clear weather result in more heat energy being absorbed and subsequently released while also limiting the amount that is carried away naturally. All of this has the impact of urban centers having temperatures between 1 and 7 ^{o}F warmer than their surroundings.[28] This can be observed in Figure 4 below, which shows the temperature differences between urban, suburban, and rural areas of Northern Delaware and Southeastern Pennsylvania.



[28] Ibid

Figure 4: Temperature and Land Cover in Northern Delaware and Southeastern Pennsylvania. Land cover data provided by National Land Cover Database through Esri.[29] Temperature data courtesy of UDEOS.[30]

The impacts of the urban heat island include increased energy consumption, increased emissions of air pollutants and greenhouse gases, negative health impacts (especially for vulnerable populations), and impaired water quality.[31] For example, elevated urban temperatures can increase the rate of ground-level ozone formation, a distinctly urban environmental problem that arises when nitrogen oxides and volatile organic compounds react in the presence of sunlight.[32]

Using Story Maps

Story maps use geography in order to organize and present information while telling the story of a place, event, issue, trend, or pattern all within a geographic context.[33] Story maps come in many varieties, each with a specific purpose. Map tours are great for presenting a linear, place-based narrative using geolocated images or videos. Map journals are good for combining narrative text with maps and other embedded content such as images or videos. Map cascades allow users to scroll through the story like they would a webpage, allowing for the integration of narrative text and other embedded content. Map series are good for presenting a series of related maps and content, such as land cover change over time. Other examples include crowdsourced story maps, short list story maps, swipe and spyglass story maps, and basic story maps.[34] The versatile tools can be used to present content during instruction or generated by students as part of a lesson or assessment.

Teaching Strategies

In order to instill in students that science is not merely a body of isolated facts but a systematic process for acquiring new knowledge, I always try to incorporate real aspects of the scientific process into the classroom. The National Research Council (NRC) lays out a framework for how to ensure that under the Next Generation Science Standards (NGSS) students have authentic scientific experiences in their classrooms even as they

[29] Multi-Resolution Land Characteristics Consortium 2019
[30] University of Delaware. 2020. "Data Services." Delaware Environmental Observing System. 2020. http://www.deos.udel.edu/data/.
[31] US EPA. n.d. "Heat Island Impacts: Heat Island Effect"
[32] Ibid
[33] Harder, Christian, and Clint Brown. 2017. The ArcGIS Book. 2nd ed. Esri Press. www.TheArcGISBook.com.
[34] Ibid

learn the bodies of knowledge of the specific sciences. When implemented properly, this framework "supports a better understanding of how scientific knowledge is produced and how engineering solutions are produced…help[ing] students become more critical consumers of scientific information."[35] This focus on process, according to the NRC, improves upon previous practices that reduced scientific procedures to isolated aims of instruction, rather than a vehicle for developing a meaningful understanding of the true scientific concept.

The central aspect of the NGSS paradigm that allows for this shift grounded in providing students with authentic science experiences for students. This is achieved by teachers implementing Science and Engineering Practices (SEPs). The eight SEPs are designed to model the scientific inquiry process from questions to conclusions, and represent a multitude of opportunities to engage students in exciting and relevant learning. This process of engaging in authentic science aids students in developing the types of critical thinking necessary to understand why the right answer is right, and perhaps more importantly, why the wrong answer is wrong. Another critical aspect of the NGSS framework is providing students with the opportunity to use common language and to recognize connections and bridge disciplinary boundaries. To that end, teachers use the Cross Cutting Concepts (CCCs) to provide this context for student learning and empower them to deepen their understanding and develop a coherent and scientifically based view of the world.[36]

This emphasis on developing a strong evidence foundation supports student understanding of fundamentals of scientific truths instead of the traditional model of asking for rote memorization of facts that didn't serve students well in their post-secondary education or in the workforce. In fact, the NRC designed the NGSS model with this specifically in mind, citing that in the past "rather than learning how to think scientifically, students [were] generally being told about science and asked to remember facts," whereas the new standards focus on student understanding by "linking concepts and practices that build coherently over time throughout K–12, thereby helping to ensure that students who meet the NGSS will be prepared to succeed in science courses in both 2- and 4-year institutions."[37] The presentation of content in this unit is phenomena-based, another hallmark of NGSS that helps students deepen their content understanding.

Hands on Learning through NGSS

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[35] National Research Council. 2012. A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas. A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas. Washington, D.C.: National Academies Press. https://doi.org/10.17226/13165.

[36] Ibid

[37] Ibid

In my classroom, I act as more a facilitator of learning than a source of information and correct answers. To that end, my teaching toolkit is full of strategies that get students *doing* science rather than *learning* science. I use a wide range of the NGSS SEPs in my classroom. In this specific unit, I will ask students to obtain and evaluate information, use models, analyze and interpret data, and construct explanations. In order to provide proper context for their learning, students use the following CCCs in this unit: systems and system models, cause and effect, and structure and function. By using these practices and concepts, I hope to train my students to think creatively, work together, and develop their scientific “muscles” for use on the AP exam in May. The specific standards addressed can be found in Appendix A: Implementing District Standards.

Collaborative Learning

I use collaborative learning for two reasons: to foster a sense of community in my classroom and because studies show that peers teaching and learning from one another to be highly effective. Collaboration and group work, whether in pairs, small groups, or more complicated jigsaw groups, is a staple in my classroom. It leads to development of high order thinking and communication, self-management, and leadership skills. It also allows me to meet with more students in less time to check for common misunderstandings and provide immediate feedback. Working collaboratively exposes students to diverse perspectives and prepares them for real life social and employment scenarios.

Encouraging Higher Order Thinking

Since students in my class need to demonstrate more than rote memorization of facts, I routinely use strategies designed to help them engage in higher order thinking. These include quick writes and Free Response Question (FRQ) stems. Quick writes is a strategy where students develop thoughtful, written responses to open-ended questions in a short period of time (typically 2-5 minutes). This allows students to practice skills critical for success in the timed FRQ section of the AP Exam. They serve as an informal assessment of student progress and allow me to identify common misunderstandings that students have while also helping students correct them and move towards mastery of the content.

Like Quick writes, FRQ stems is a strategy that also aids students in their preparation for the AP Exam while helping them master the content at hand. It involves using prompts with students that mimic the action verb and language of the FRQs students encounter on the exam. These include “identify”, “describe”, “discuss”, “explain”, “predict”, “propose and justify”, and “calculate.” When I ask students to respond to prompts I make a conscious effort to use these terms so that students understand how to approach each specific term. I spend considerable time in the beginning of the course modelling this and drilling students so that by the time they reach this point in the year it is almost second nature.

Direct Instruction

While the practice of direct instruction is recognized as having its limitations on improving student mastery of content, I find it necessary in the AP curriculum due to the volume of material that needs to be covered. I use a small amount of direct instruction in most classes, but to maximize its effectiveness I encourage interaction by strategically asking questions, using guided notes, and turn and talks. I try to limit direct instruction to fifteen to twenty minutes each day.

Classroom Activities

Pre-Reading

To prepare for this unit, students read module 30 on urbanization in the course textbook, Environmental Science for the AP Course by Friedland and Relyea. Teachers using a different textbook can reference the course outline published by the College Board and assign the corresponding chapter or module in their own textbook.

Day 1: Introduction to Land Use

Students are introduced to the topic of land use by examining the "Here's How America Uses Its Land" story map on Bloomberg.com.[38] As students scroll through the map they complete a notice and wonder chart. When complete, students discuss their notices and wonders with their small group and look for common observations and questions. Each smaller group shares out to the larger classroom community. I record each group's notices and wonders on the board and use them to facilitate a discussion focusing on the geographical distribution of land uses across the country first, then on the total amount of land dedicated to each major category, and concluding with an emphasis on the relatively small and non-continuous amount of land dedicated to urban spaces. After this discussion, students complete a quick-write to summarize their key takeaways from the story map.

Students then move on to study land use in Northern Delaware (Figure 1). They complete another notice and wonder as they view the map and are asked to compare and contrast this map with the larger one of the US they viewed in the beginning of the lesson. Students should notice that our part of the state is much more heavily developed than the US as a whole and should relate that to the higher than average population density. They are also asked to make some predictions about what types of environmental issues might

[38] Merril and Leatherby 201)

be associated with this high degree of developed land. Students discuss this with their small groups and share with the larger classroom community.

Students conclude class by reading a brief EPA article about the relationship between land use and environmental impacts.[39] As they read, students keep track of the key points in their notes. Along with their notices and wonders and quick writes, students use their notes to respond to the following FRQ stems: Identify and describe the major environmental impacts of both land development and agricultural practices; Explain which will have a greater impact on Northern Delaware using evidence from today's lesson.

Day 2: Urbanizations Basics

Now that students have an idea of how land is used in the US and in a portion of our school community, they turn their attention to the phenomenon of urbanization. This lesson incorporates some of the material students read about in the EPA article on Day 1 of the unit, with an emphasis on environmental impacts related to land development.

Students examine several graphs and maps to provide some global context to urbanization. The data are available at ourworldindata.org/urbanization.[40] The specific graphs and maps of interest include "Number of people living in urban and rural area, World, 1960 to 2017", "Share of people living in urban areas, 2017", "Urbanization over the past 500 years, 1500 to 2016", and "Share of the population living in urban areas, 2050." For each graph or map, students are tasked with identifying the key message each is attempting to convey. Students then work collaboratively to share and refine their key messages into one mutually-agreed upon message for each map.

Then, through direct instruction, students are introduced to the main causes and consequences of urbanization described above. They keep track of their learning in their notes, using the FRQ stems of "identify" and "describe" as starting points.

Day 3: Land Use Change in Delaware

At this point in the unit, students have accumulated a wealth of knowledge about urbanization and land development. Using this as a base, students now turn their attention to Delaware in order to compare and contrast land use change and its environmental consequences in its three counties. Students work in jigsaw groups to examine land use change in New Castle, Kent, and Sussex Counties. In their specialist groups, students work with other group members on the same county. Upon return to their home groups

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[39] US EPA. n.d. "Land Use | EPA's Report on the Environment (ROE) | US EPA." Accessed December 8, 2020. https://www.epa.gov/report-environment/land-use.
[40] Global Change Data Lab 2020

students share their findings with the members who studied other counties and work together to create a digital presentation in either Google Slides or Prezi, along with a one-page summary of their findings. Specialist groups start by examining the time series land cover maps in Figure 5.

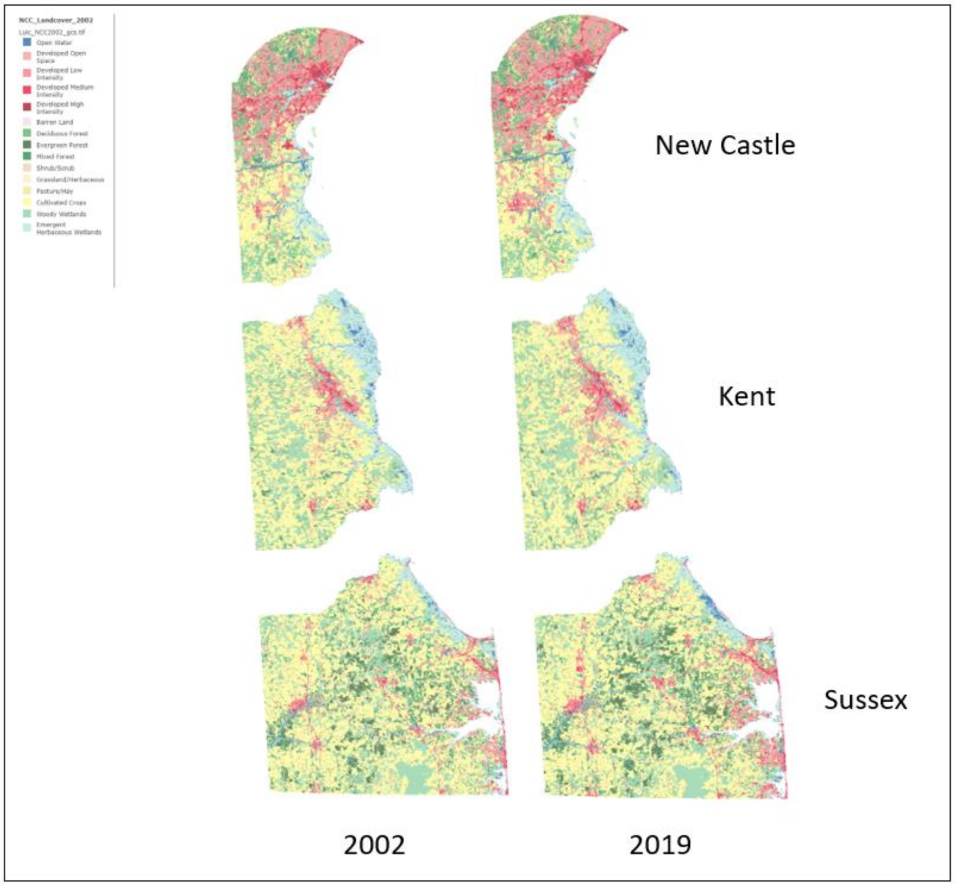

Figure 5: Land cover in New Castle, Kent, and Sussex counties from 2002 (left) to 2019 (right).[41] Data provided by National Land Cover Database through Esri and ArcGIS.

When analyzing the maps, students are first asked to identify and label key features (like roads, cities, towns, etc.). They are provided with larger, individual images for each county and year. Then, they use the legend to look at the specific land cover changes that are evident in each county between 2002 and 2019. Students assigned to New Castle

[41] Multi-Resolution Land Characteristics Consortium. 2019. "USA NCLD Land Cover." Esri. 2019. https://landscape10.arcgis.com/arcgis/rest/services/USA_NLCD_Land_Cover/ImageServer.

County (top of Figure 5) should see significant land development in the Middletown area and along US 13 and DE 1. This is demonstrated by a higher percentage of red and a lower percentage of the green and yellow hues associated with forested and agricultural land, respectively. Students assigned to Kent County (middle of Figure 5) should see similar development along US 13 and DE 1, with the most identifiable growth in the Smyrna/Clayton area. Students assigned to Sussex County (bottom of Figure 5) should be able to identify significant development along inland bays. Some of this growth is at the expense of wetlands along the bays, while the rest of it is at the expense of agricultural land.

After analyzing the maps, students describe the predominant land cover changes and make predictions on what drives those changes. Finally, they return to the EPA article on land use changes to associate specific environmental consequences with their observations. Now, students return to their home groups to share their findings with those who worked on other counties.

Transition to Stormwater Runoff Unit

After completing this unit, students use their knowledge to complete the unit I developed with the Yale National Initiative on stormwater runoff and green infrastructure. In short, students apply their knowledge of land use and its impact on the environment to study the phenomenon of stormwater runoff in our school community and propose green infrastructure solutions to mitigate its negative effects. These units were designed to be taught in tandem with one another and can easily be modified for teachers outside of Delaware.

Appendix A: Implementing District Standards

Students satisfy the following science practices as outlined by the College Board in the AP Environmental Science Course and Exam Description: explain environmental concepts, processes, and models presented in written format and propose and justify solutions to environmental problems. Students satisfy the first of those practices during the activity on using stormwater models and the second during the activity on planning stormwater management practices. Students satisfy both of these practices on the summative FRQ. I also use several broader practices laid out by the NGSS framework for learning, including the following SEPs: obtain, evaluate, and communicate information, develop and use models, analyze and interpret data, and construct explanations. Students use this combination of AP and NGSS practices to meet AP Environmental Science Learning Objectives EIN-2.M (describe the effects of urbanization on the environment) and STB-1.B (describe methods for mitigating problems related to urban runoff).

Appendix B: Virtual Teaching Strategies and Classroom Activities

This unit has been written for standard in-person instruction. However, it can easily be adapted for use in a virtual instruction environment. If I were teaching this unit virtually, I would begin by creating a hyper-doc in Google Docs. This hyper-doc would be the equivalent of a student notebook and provides the necessary structure students in a virtual environment need in order to maintain some organization and keep track of their learning. The hyper-doc serves as the one-stop shop for all resources related to the unit. Links to any external resources are provided, along with reading and writing prompts and space to respond to those prompts. Each day of the unit would be its own page in the hyper-doc. students work through the assignments at my guidance, I can monitor their progress in real time and provide targeted support for students who are struggling or falling behind.

Specific to this unit, the hyper-doc would include a summary of the learning targets at the top, along with a list of required pre-readings. Day 1 would include a live link to the article on land use in the US as well as some select screenshots of particularly important or relevant maps from the site. Students would use Jamboard to complete their notice and wonders before summarizing their key takeaways in the document. They would then examine Figure 1, which would be embedded in the document and repeat the Jamboard process for this map. Students would then complete their compare and contrast in the document. Day 1 would conclude with students reading the EPA article on land use and the environment, which would be linked in the document along with a space for them to take notes on the key points.

Day 2 would revolve around the graphs/maps from the Ourworldindata website. Screenshots of the graphs/maps identified above would be inserted into the document. Since this day is meant to be done collaboratively, students could work in small breakout groups or collaborate on one shared document as they examine the information and make interpretations (depending on the technology available to the teacher and students). The direct instruction on urbanization basics could be delivered live through a digital media presentation or recorded for students to watch and take notes on their own time. Either way, students would have guided prompts (with FRQ stems embedded into those prompts) to complete in order to keep them engaged as they watch and listen.

Like Day 2, Day 3 of this unit is designed to be done collaboratively, so students would again need to work in breakout groups or on shared documents in both their home and specialist groups. Each specialist group would be provided with their necessary maps (these could be embedded in the document ahead of time for students or shared with them once their groups have been assigned). From there, students would collaborate to identify the major changes and make predictions about what drives those changes and what environmental consequences those changes might have. Students would then return to their home groups (either in breakouts or on a new shared document) to share their findings with their group members.

Alternatively, teachers who don't wish to provide this level of structure for their students can post each of the resources in an online learning management system and create individual assignments for each task students complete.

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This is my course textbook. Though it does not follow the APES CED chronologically, it is laid out by module, so it is easy to assign parts of chapter while still following the CED order. It had great visuals and practice questions.

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Another useful resource for teachers wanting to know more about how land use change has impacted the environment

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Notes