The Global Oil Market

A spatial perspective of this complex phenomenon

— by Jeff Blossom

Introduction

Problem

The economic health and overall welfare of nearly every country depends on oil. In a global economy, few nations could maintain an adequate standard of living without international trade. Global trade provides increased access to an enormous variety of resources and facilitates widespread distribution of goods produced in specific parts of the world to a much larger market.[1] The global economy relies on oil-based fuels like gasoline, diesel, and jet fuel to efficiently transport resources, goods, and people. Oil also provides energy to heat homes and is a core ingredient in hundreds of products such as medicines, fertilizers, clothes, tires, and linoleum. The volume of oil traded on the global economic market far surpasses that of any other commodity.

The problem is that oil production will peak in the next few years, yet oil demand is expected to continue to rise. Alternative energy sources are being developed but have so far proved unable to match the high-energy density, portability, safety, and ease of handling that oil offers.[2] The dependence on oil also presents environmental concerns. Therefore, the efficient use of oil is critical to allow time for alternative energies to be developed. How can we start to address this problem?

Location

Global in scope

Time to complete the lab

2 hours

Keywords: cartographic representation and techniques, classification methods, data analysis, data classification, economic markets, geographic clustering and dispersion, global economics, global oil market, map rendering in 2D and 3D, maritime oil routes, oil consumption, oil transport, pipelines, spatial analysis, thematic mapping, visualization tools, and world geography

Level of GIS experience

Advanced

Data used in this lab

- Global country boundaries (Esri Data & Maps 2008)
- Oil and gross domestic product data (Central Intelligence Agency World Factbook)
- Oil pipeline locations
- Geographic coordinate system: WGS 1984
- Datum: WGS 1984
- Projected coordinate system: World Robinson

Student activity

When fuel derived from oil is combusted to form energy, various gases, such as sulfur dioxide, nitrous oxide, and carbon dioxide, are emitted into the atmosphere. The first two gases are causes of smog and acid rain, while carbon dioxide emissions exacerbate the earth's greenhouse effect, possibly causing climate change.[3] More than 81 million barrels of oil are produced each year. As this enormous volume is extracted from the earth, transported, refined, transported again, and consumed, potential and actual environmental contamination pose serious concerns to life on earth.

For example, the Deepwater Horizon spill spewed roughly 53,000 barrels of oil per day into the Gulf of Mexico for nearly three months in 2010, heavily damaging the Gulf's marine and wildlife habitats. The spill killed thousands of marine and coastal animals, altered the chemistry of the Gulf, and caused the closing of fisheries in 36 percent (86,985 square miles) of the Gulf's federal waters.[3] The full environmental impact of this disaster is yet to be determined as ocean currents continue to disperse the spilled oil.

Given the problems outlined above, where does one begin trying to understand the complex phenomena that the global oil market presents? You will explore these issues by examining the geographic landscape of oil production, consumption, and transportation.

How is the market price of oil determined? For the past hundred years or so, oil prices have either been (a) fixed by a small group of oil-producing companies or nations or (b) determined by a competitive market with many producers. Early in the twentieth century, oil producers consisted of several western multinational (US, British, Dutch) oil-producing corporations. These corporations invested heavily in oil extraction infrastructures, especially in oil-rich areas like the Middle East and Latin America.[1] Through the 1950s, '60s, and '70s, discoveries of greater quantities of oil prompted countries in the Middle East to assert nationalistic control of their oil. In 1960, Iran, Iraq, Saudi Arabia, Kuwait, and Venezuela formed the Organization of Petroleum Exporting Countries (OPEC)

in an attempt to control a greater share of incomes generated by controlling oil supply. In the 1980s and '90s, new producers, such as Mexico, Norway, and Russia, began to produce oil in earnest and became global players in the oil industry. Because the geopolitical power of these various oil-producing entities fluctuates, oil supply and subsequent price determination become complicated issues.

On the demand side, while every nation needs oil, about half of the world's countries produce no oil. This requires oil transportation to satisfy global demand. Because transporting oil is costly, oil is transported to the nearest market first to minimize this cost.[4] Some countries, like the United States, have traditionally demanded large amounts of oil, and countries with emerging economies, like China, demand more oil each year. Generally, there is a positive correlation between oil demand and the amount of industrialization in the country.

Are the world's top oil consumers also its top producers? Where is oil produced and consumed, and how does this distribution relate to each nation's population, land area, and gross domestic product (GDP)? What countries have an oil surplus (or deficit), and are there spatial patterns between these national oil budgets? How effectively do terrestrial and maritime oil transportation routes connect the producers and consumers? You will explore these sorts of questions in this lab.

The unit used to measure oil is a barrel of oil (bbl), which equals approximately 42 gallons. In this lab, you will examine total bbl produced and consumed on a national basis and create 2D and 3D maps of production and consumption. An overall measure of a country's wealth is GDP. National GDP data will be examined, mapped, and compared to oil production and consumption data. Pipelines transport large amounts of oil across land. You will add locations of major oil pipelines to the map and analyze them in relation to production and consumption data. Oil tankers are used to transport oil across oceans and other water bodies, always attempting to use the most direct route. You will map water bodies important to the transportation of oil and identify major transportation routes.

You will

- ▪ **Prepare the data**
  - • Calculate the length of pipelines per country.
  - • Map and calculate distances of maritime oil transport routes.
  - • Normalize oil production and consumption data by population and land area.
  - • Sort oil production, consumption, and GDP data to identify the top five producers and consumers.

- ▪ **Create maps**
  - • Produce thematic maps of the consumption, production, GDP, oil budget, pipeline, and maritime data.
  - • Produce thematic maps in 3D of the production and consumption data.

- ▪ **Analyze results**
  - • Compare the social, political, and economic similarities and differences of the top oil producers and consumers.

- Examine the various thematic maps to identify any geographic clustering or dispersion.
- Evaluate the effectiveness of the various cartographic representations created.

PREPARE YOUR WORKSPACE

Data preparation, storage, and backup are basic and crucial to any project. It is a good practice to store all your data within a single folder on your computer or storage device.

1   Create a *SpatiaLABS* folder and an *Oil* subfolder in the C:\ folder.

2   Transfer the data for this lab into the C:\SpatiaLABS\Oil workspace.

3   Examine all data in the *Data* folder (you should have *oil_budget.shp* and *oil_pipelines.shp*).

OIL CONSUMPTION

ANALYZE

1   Launch ArcMap and add *oil_budget.shp*.

Question 1: *What attributes are present in oil_budget.shp, and what do they represent?*

Question 2: *What are the top five oil-consuming countries?*

2   Create a map symbolized by oil consumption, similar to map 1 below. Choose a classification method that best communicates the disparities of global oil consumption. Include a legend and list the top five consumers on the map.

Question 3: *What social, political, and economic similarities or differences exist among the top five oil-consuming countries?*

Question 4: *What classification method best communicates the global variation in oil consumption?*

3   Save the *oil_budget.shp* file symbolized by oil consumption as a layer file.

4   Open ArcScene and add the oil consumption layer file. Create a map with a perspective to effectively show the global disparities in oil consumption extruded by height (see map 2).

Question 5: *What effect does rendering the map in 3D have?*

5   Back in ArcMap, add a new floating point consumption per capita field with at least three decimal places to the attribute table and calculate values for it using the existing fields.

Question 6: *What equation did you use to calculate consumption per capita, and what units are the resulting values in?*

Question 7: *What are the top five oil-consuming countries per capita?*

Question 8: *What geographic similarities do these countries have?*

6   View the histogram of oil consumption per person, and examine the numeric distribution. Experiment with different classification methods and the number of value ranges and how these affect the map. Customize the map to best display the range of values (see map 3). Include a legend on the map and a list of the top five consumers per capita.

7   Create a 3D map extruding oil consumption per capita in ArcScene, similar to map 4. Adjust the extrusion factor and use the pan, zoom, and navigate tools to effectively display the nations consuming the most and least oil per capita.

Question 9: *Which map (2D or 3D) is more effective at communicating oil consumption per capita? Why?*

Question 10: *For the 3D map, what extrusion factor did you use and why?*
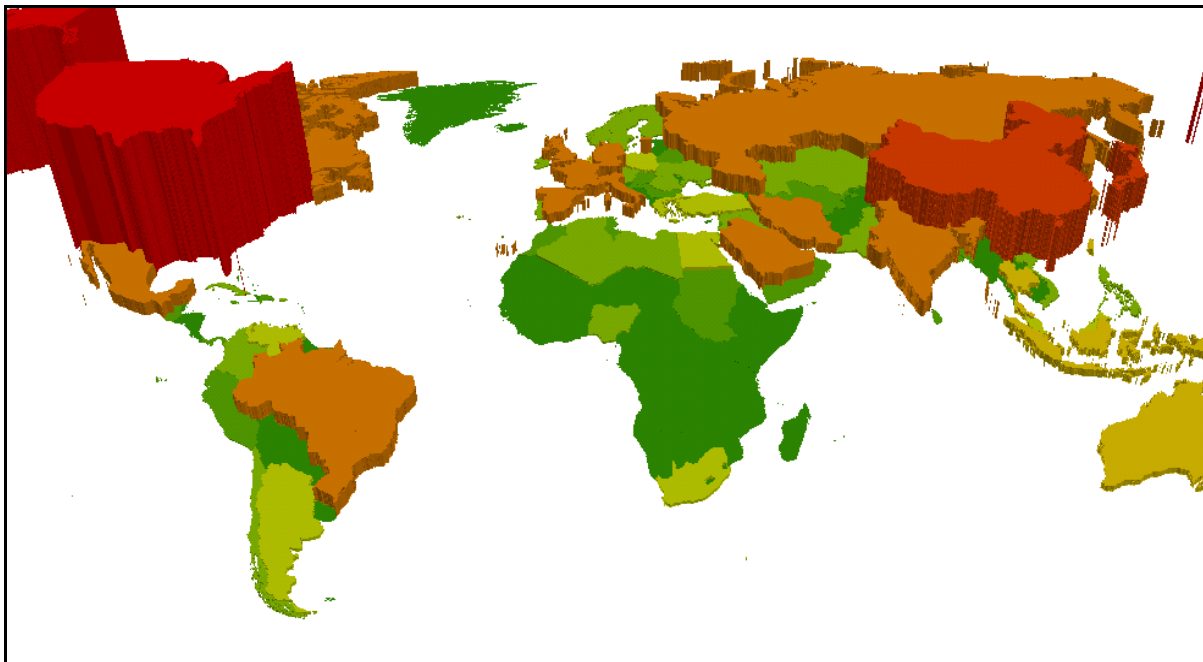
Question 11: *For the 2D map, what other cartographic techniques could be used to better identify the top five oil consumers per capita?*
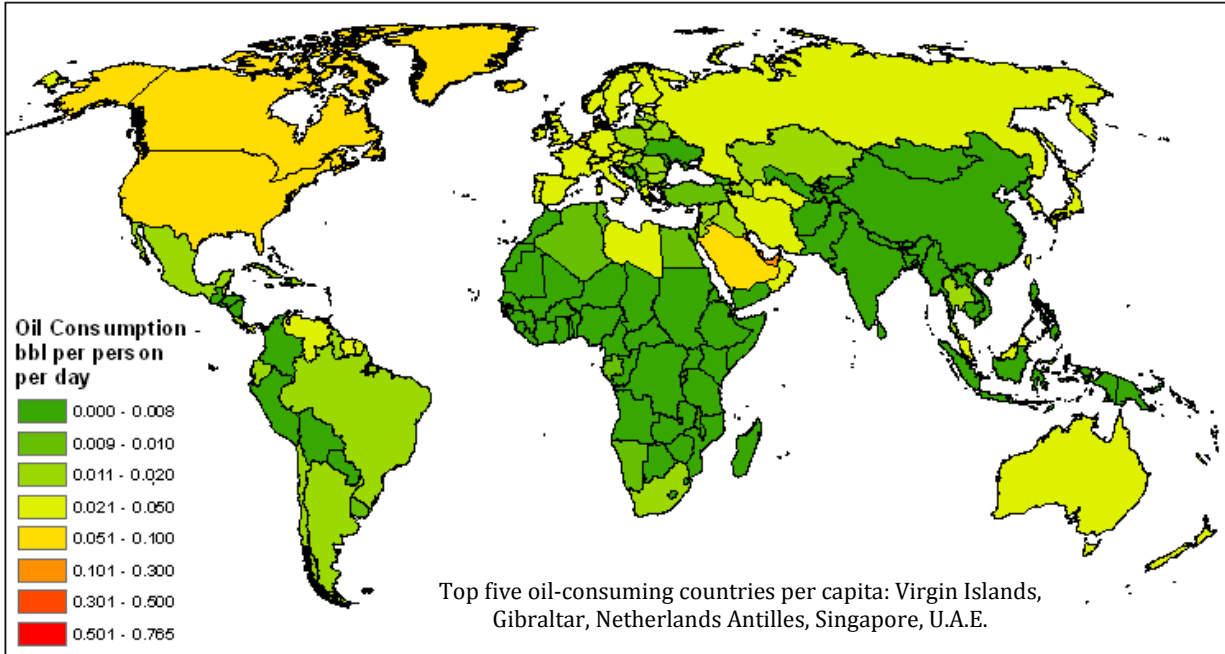
VISUALIZE

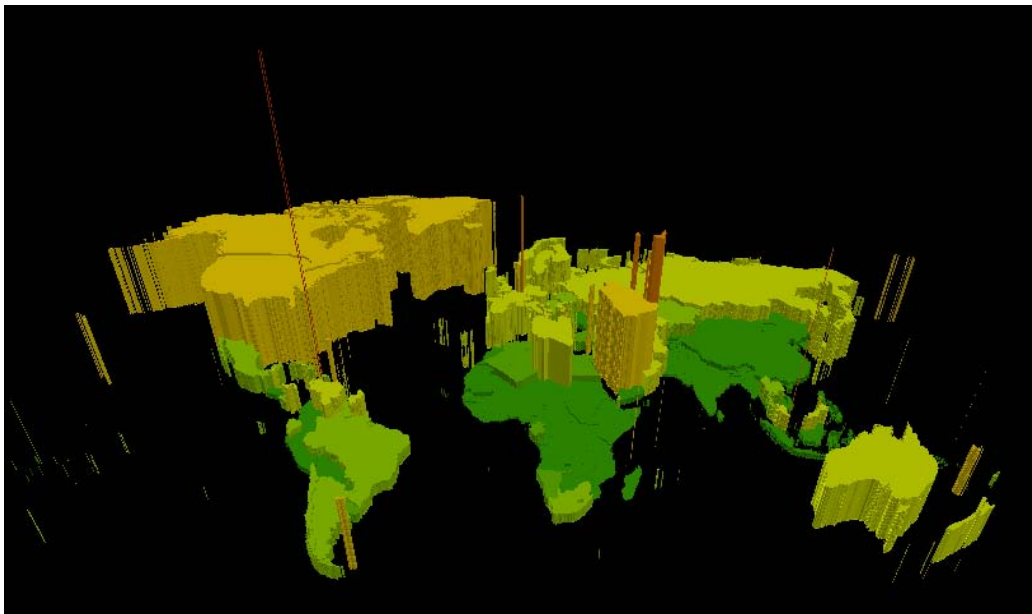Map 1 shows global oil consumption data.

Top five oil-consuming countries:
United States, China, Japan, Russia, and India
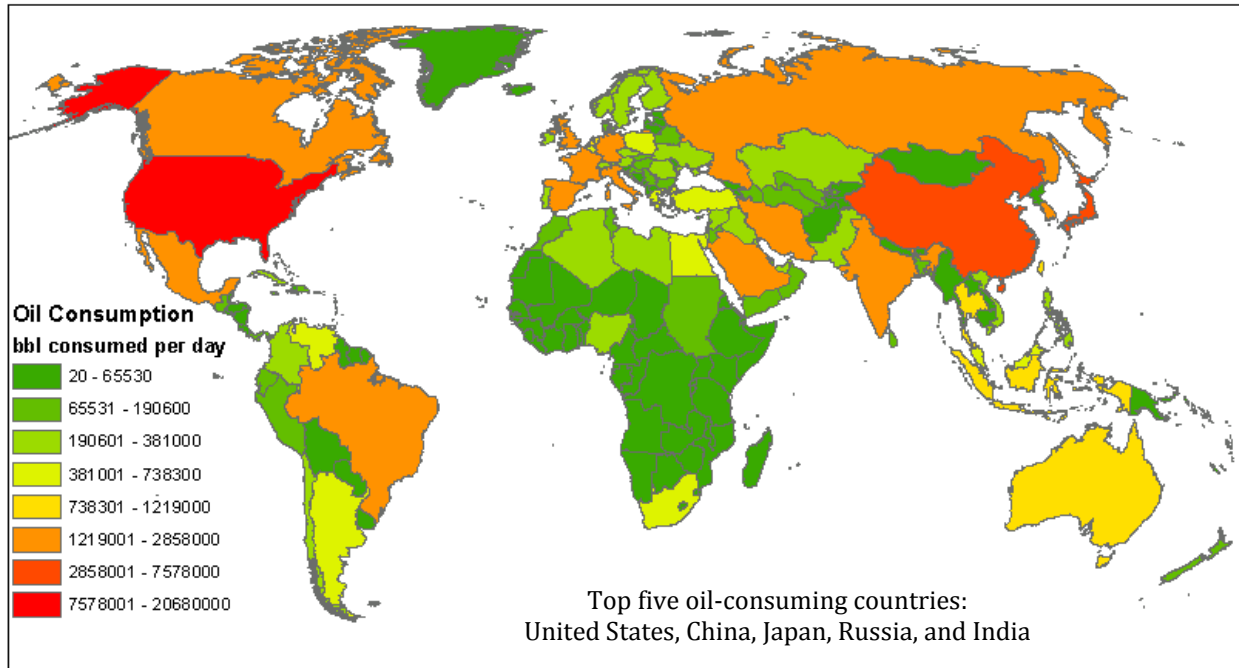
Map 2 shows global oil consumption data extruded into 3D.

Map 3 shows global oil consumption per capita.

Oil Consumption - bbl per person per day

- 0.000 - 0.008
- 0.009 - 0.010
- 0.011 - 0.020
- 0.021 - 0.050
- 0.051 - 0.100
- 0.101 - 0.300
- 0.301 - 0.500
- 0.501 - 0.765

Top five oil-consuming countries per capita: Virgin Islands, Gibraltar, Netherlands Antilles, Singapore, U.A.E.

Map 4 shows global oil consumption per capita extruded in 3D.

OIL PRODUCTION

ANALYZE

1   Open the attribute table of *oil_budget.shp* and examine the values in the production field. Add a new floating point production per land area field with two decimal places and calculate values for it.

2   Create thematic maps of oil production and oil production per land area similar to maps 5 and 6 below.

Question 12: *What equation did you use to calculate production per land area, and in what units are the resulting values?*

Question 13: *What social, political, and economic similarities or differences exist among the top five oil-producing countries?*

Question 14: *How many countries produce oil? What are the top five producers of oil? What are the top five producers of oil per land area?*

**Question 15:** *Why is land area used to normalize oil production data?*

Question 16: *Which map might be more visually descriptive if rendered in 3D?*

Question 17: *Is geographic clustering of high producers visually apparent on either of the maps?*
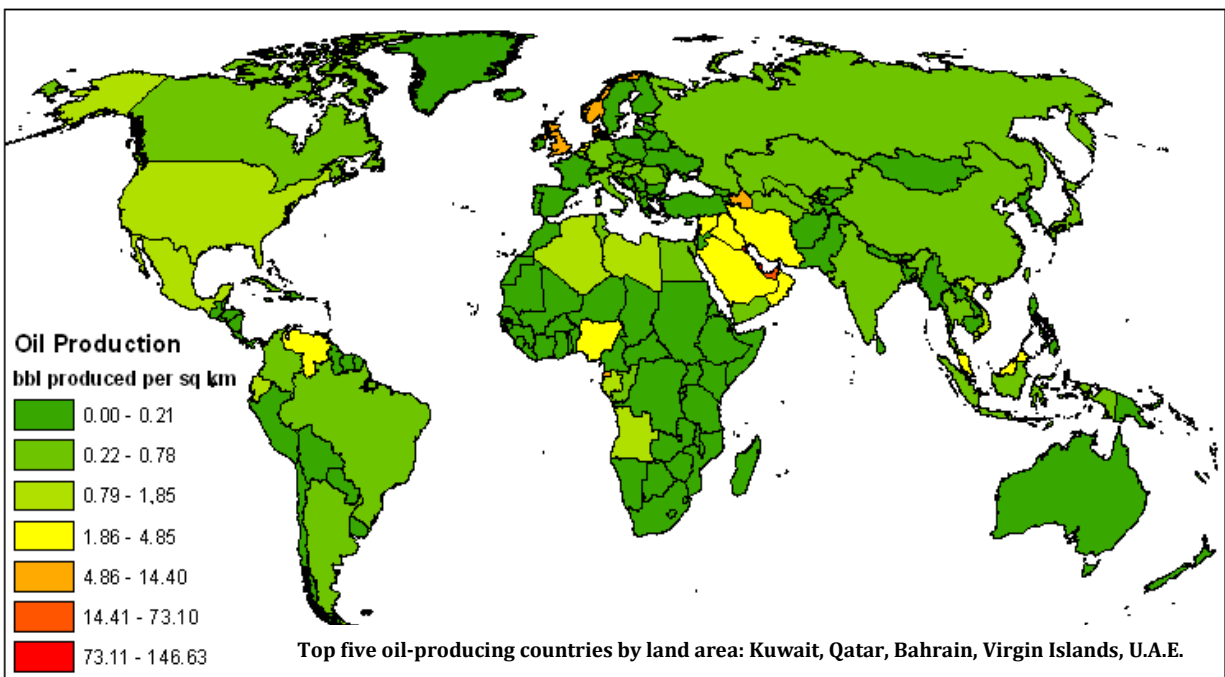
Question 18: *What continents are most deficient in oil production?*

VISUALIZE

Map 5 shows oil production.

Top five oil-producing countries: Saudi Arabia, Russia, USA, Iran, China
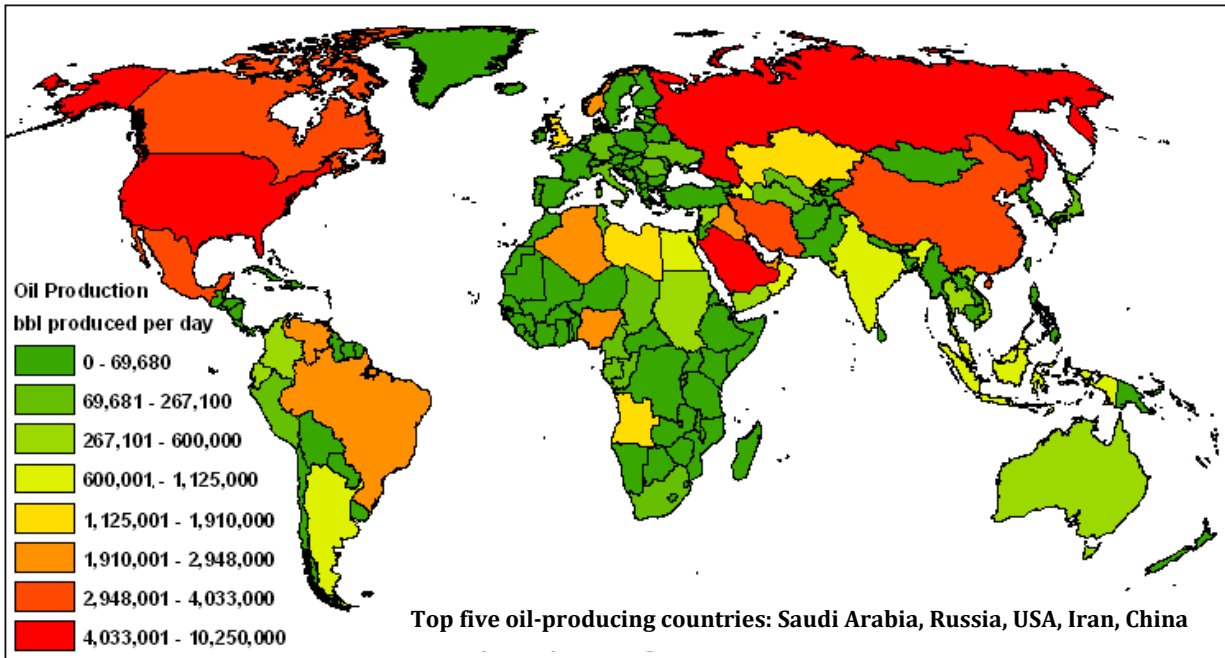
Map 6 shows oil production by land area.

Top five oil-producing countries by land area: Kuwait, Qatar, Bahrain, Virgin Islands, U.A.E.

OIL BUDGET AND GDP MAPS

ANALYZE

1   Create an oil budget long integer field in *oil_budget.shp* and calculate it equal to (oil production – oil consumption).

2   Create an oil budget map showing countries with oil surpluses in blue and deficits in red (map 7).

Question 19: *Are countries with oil deficits globally clustered or dispersed, and how might this affect the transportation of oil?*

3   Examine the data in the GDP attribute in the *oil_budget.shp* shapefile and create a thematic map of GDP, listing the top five nations on the map (map 8).

**Question 20:** *How do the top five nations in GDP compare to the top five oil producers?*

Question 21: *Compare the GDP map and oil production map. What similarities and differences do you find?*

Question 22: *Compare the GDP map and oil consumption map. What similarities and differences do you find?*
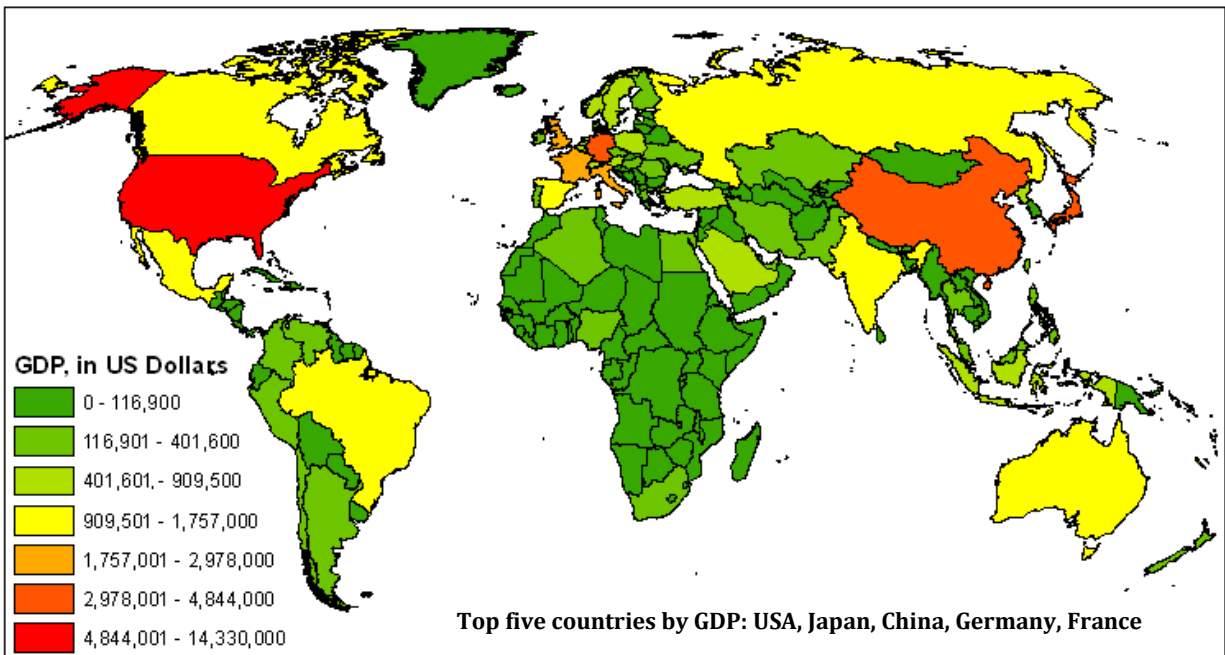
Question 23: *Would it make sense to normalize GDP by population or area?*

VISUALIZE

Map 7 shows oil surplus/deficit.
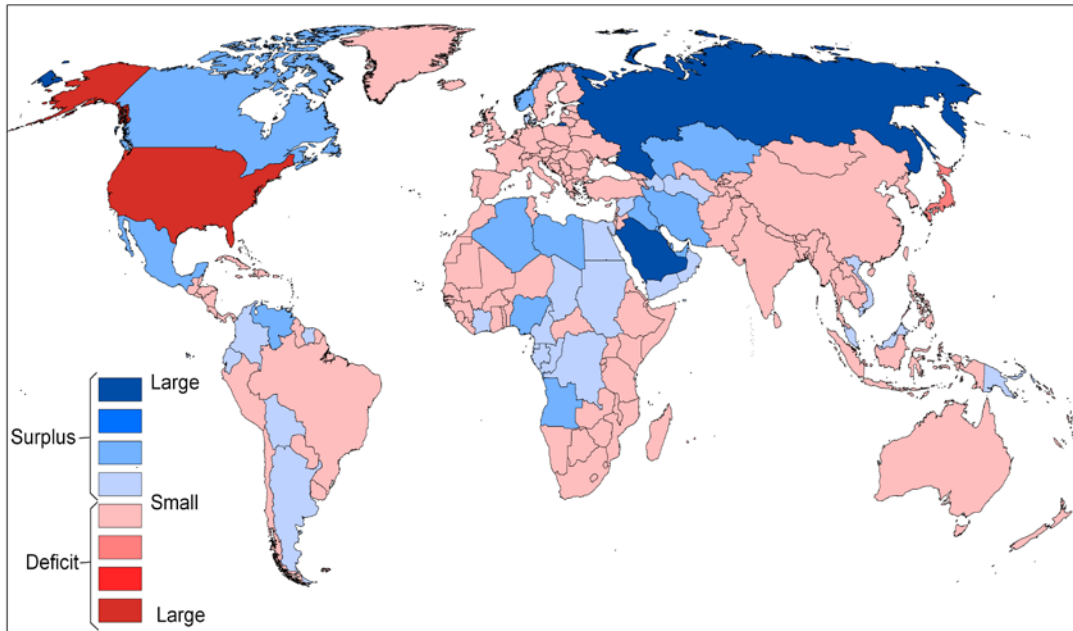
Map 8 shows GDP.

OIL PIPELINES AND MARITIME TRANSPORT

ANALYZE

1   Add the *oil_pipelines.shp* shapefile to the map. Examine the status field in the attribute table.

Question 24: *What countries have many proposed or in-progress pipelines?*

Question 25: *How many countries have major pipelines in them?*

2   Process the *oil_pipelines* shapefile so that total pipeline length per country can be calculated, then calculate this value into a new field.

3   Process the *oil_pipelines* shapefile to calculate kilometers of pipelines per square kilometer (km), and calculate this value into a new field.

4   Create two maps: (1) Countries shaded by total length of pipelines and (2) countries shaded by length of pipelines per square km. Include the pipeline vectors, then list the top five countries on both maps (see maps 9 and 10).

Question 26: *Briefly describe each continent's pipeline distribution.*

Question 27: *What continent has very little oil production yet has a large length of pipeline?*

Question 28: *Would either of these maps be more descriptive if rendered in 3D?*

5   On a world map, identify the original Middle Eastern OPEC countries—Iran, Iraq, Saudi Arabia, and Kuwait.

Question 29: *What water body do these countries nearly surround?*

Additional information: The bulk of transported oil (62 percent) uses maritime transportation. The Persian Gulf is a major origin, and from this point, maritime routes reach Europe through the Suez Canal, Japan through the Strait of Malacca, and North America through the Cape of Good Hope. Other important oil shipments are from Africa to North America and Europe, from the North Sea to Europe, and from South America to North America.[2]

6   Create a maritime oil transport map that labels all the place-names mentioned in the paragraph above, map the transportation routes mentioned, and calculate the length of each route.

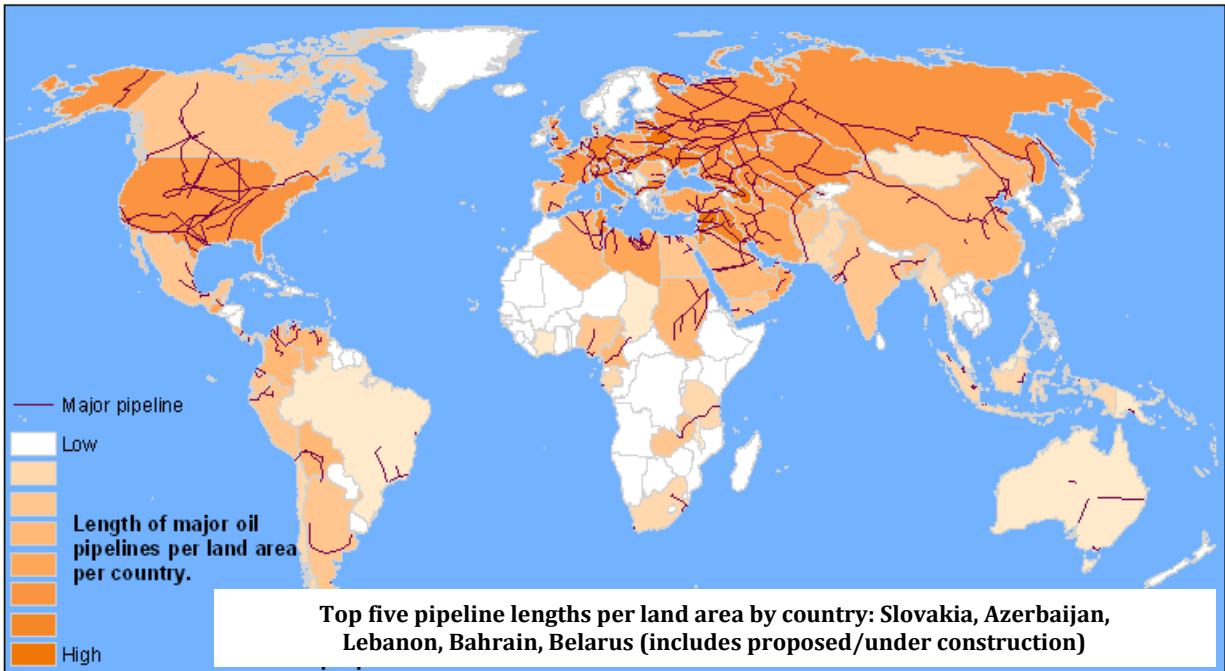**Question 30:** *What is the longest maritime transportation route?*

Question 31: *Examine the geographic location of Iraq. Do you think it is more important for Iraq to transport oil by land or by sea? Why?*

VISUALIZE

Map 9 shows major oil pipeline length per country and pipeline locations.
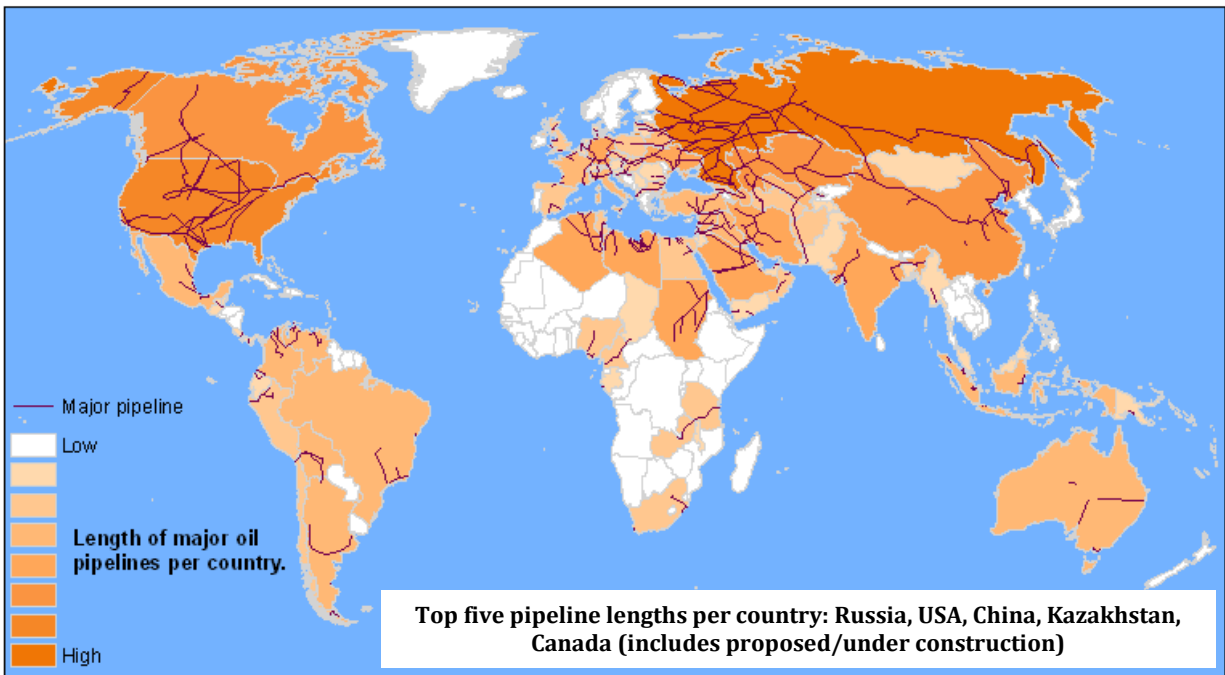
Map 10 shows major oil pipeline lengths per land area per country and pipeline locations.

Top five pipeline lengths per land area by country: Slovakia, Azerbaijan, Lebanon, Bahrain, Belarus (includes proposed/under construction)

Submit your work

Submit the following:

- Map 1—Thematic map displaying oil consumption, with legend and top five oil consumers indicated
- Map 2—Oil consumption extruded in 3D
- Map 3—Oil consumption per capita, with legend and top five oil consumers per capita indicated
- Map 4—Oil consumption per capita extruded in 3D
- Map 5—Oil production, with legend and top five oil producers indicated
- Maps 6—Oil production by land area, with legend and top five oil producers by land area indicated
- Map 7—Oil surplus/deficit map, with legend and symbolized with a range of blues for surplus and a range of reds for deficit
- Map 8—GDP, with legend and top five countries listed
- Map 9—Major oil pipeline locations, with pipeline lengths per country (thematic shading), legend, and a list of the top five nations in pipeline length
- Map 10—Major oil pipeline locations, with pipeline lengths per country per land area (thematic shading), legend, and a list of the top five nations in pipeline length per land area

- Map 11—Maritime oil transport map, with important places labeled and transportation routes identified

References

1. Rodrigue, Jean-Paul, Claude Comtois, and Brian Slack. 2009. "Transportation and the economy." *The Geography of Transport Systems*. New York: Routledge, 352.
    `http://people.hofstra.edu/geotrans/eng/ch5en/appl5en/oiltransportation.html`

2. Mast, Tom. 2005. "Oil and its alternatives: Why they are so important." *The San Diego Union-Tribune* (March 9)*.*
    `http://www.signonsandiego.com/uniontrib/20050309/news_lz1e9mast.html`

3. Wikipedia.org: **http://en.wikipedia.org/wiki/Fossil_fuel**

4. US Energy and Information Administration Independent Statistics and Analysis.
    `http://www.eia.doe.gov/pub/oil_gas/petroleum/analysis_publications`
    `/oil_market_basics/trade_text.htm#Global%20Patterns%20of%20Oil%20Trade`

Credits

Data

Global country boundaries: from Esri Data & Maps 2008, courtesy of ArcWorld

Oil and gross domestic product data: Courtesy of Central Intelligence Agency

Oil pipeline locations: Courtesy of Center for Geographic Analysis, Harvard University

Instructor resources

Context for the lab

This SpatiaLAB is primarily written for college undergraduates studying world geography and global economics.

This lab shows how to map information usually analyzed only in tables. It is intended to promote thinking about the global oil market, individual country oil budgets, and transportation of oil.

You should guide students regarding what data classification methods to use, how many classification categories make sense, color schemes to use, and whether rendering the map in 3D makes sense.

Using a spatial approach, a geographic information system (GIS) can be one of the most useful tools to explore spatial data and perform data analysis and mapping.

This lab will use oil consumption, production, GDP, and pipeline location data.

Students will be asked to answer several questions and make 11 maps.

Analysis and visualization tools

ArcGIS 9 or 10 is required to complete this lab.

Data information

The dataset included with this lab contains the *oil_budget* and *oil_pipelines* shapefiles, both in World Robinson projection.

Data sources

Oil consumption, production, and GDP: `https://www.cia.gov/library/publications/the-world-factbook/`

There are multiple sources of oil production, consumption, and GDP information. The Central Intelligence Agency World Factbook was chosen as a data source due to its reputation for providing comprehensive, unbiased data and the ease with which the data could be downloaded into a format compatible with GIS. Most consumption and production data was estimated for 2008; some countries only had 2007 estimates.

Major oil pipelines: `http://www.theodora.com/pipelines/`

The pipelines were digitized from maps provided at Theodora.com. These maps were compiled from multiple sources and presented for public use in image format. The Center for Geographic Analysis at Harvard University digitized pipelines from these maps (the raw vectors were not available) for mapping and analysis as part of an instructional workshop taught in August 2009 at Harvard titled "Oil and the Contemporary Globe—A Multi-regional, Multi-subject Study of the Modern World's Foundation." Emphasis was placed on capturing major pipelines on a small geographic scale. Larger-scale maps depicting more pipelines exist, but pipelines from these maps were not captured due to the project objective of capturing global pipelines at a small geographic scale.

Country boundaries: Esri Data & Maps 2008

This country boundary shapefile was used because it was easily available to the author; it was delivered with the GIS software media. Any country boundary shapefile representing the roughly 200 countries in the world could be used just as effectively.