Analysis on increasing levels of CO2 emission in the United States

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Abstract- CO2 emission levels have been increasing with every passing year and can have severe negative impacts. Burning fossil fuel releases carbon dioxide and other greenhouse gases can cause serious problems to human health and the environment. With the increasing need of energy fossil fuels are being burnt at a tremendous rate which can lead to problems like shrinking water supplies, severe impacts on weather, geographical changes, affects food supply. In this project, we will make of GIS software to answer the following questions (1) The CO2 emission levels all around the US (2) Areas where C02 emission is the highest. We will use the following methods to answer the above questions (1) Identifying areas with high C02 emission levels (2) Performing spatial analysis to uncover patterns present in the data (3) Using cartography principles to create visualizations and display the results.  
  
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# **Introduction**

Greenhouse gases are known for trapping heat in the earth’s atmosphere making the planet warmer in this process. These gases include water vapor (H2O), carbon dioxide (CO2), methane (CH4), ozone and dinitrogen oxide (N2O), all of these gases are also naturally present in nature. In addition to the above gases there are also man-made greenhouse gases that can directly or indirectly effect the environment leading to harmful effects like global warming. chlorofluorocarbons (CFSs and HCFSs), hydrofluorocarbons (HPCs, PFCs and SF6) and bromine compounds are some of the man-made greenhouse gases. From all these gases CO2 emission have increased significantly over these past years. The start of the industrial revolution has led to an increase in the burning of fossil fuels like coal, crude oil and natural gas which in turn has increased the CO2 level in the air. According to a study done by Investopedia in 2018 [9], United States accounts for 5,416 million metric tons of CO2 emission and ranks second in the world as one of the highest emitters of annual carbon dioxide. This can cause adverse effects on climate, cause air pollution, human health, and in in some extreme cases cause extreme heat. CO2 levels currently are very high

Transportation, electricity production, industries, commercial and residential, agriculture, land-use and forestry some of the primary sources of CO2 emission in the United States [8]. According to an annual report published by the United States Environmental Protection Agency, transportation electricity production and industry accounted for 22.2%, 26.9% and 22% respectively CO2 gas emissions in 2018. In order to reduce the CO2 levels, we need to determine which areas of US release the highest amount of CO2.

For this project we are going to make use of GIS principles to preform spatial analysis on the data to create joins and relationships. We will be making use of data collected over the past 10 years from 2006-2017 from Data world bank for this analysis. Using this data, we will be able to cluster the states according to their levels of CO2 emission. We will also be plotting coal mine facilities and crude oil pipeline which are one of the primary sources of CO2.

# **Problem**

**2.1 Problem Statement**

In order to identify the areas in the US where CO2 emission is the highest, we are going to make use of past 10 years dataset to study the increasing levels of CO2 emission. For this we are going to make use of GIS principles to create visualizations, perform spatial analysis, generate relationships etc. Over the years fossil fuel is being burnt at a high rate which has been increasing the concentration of greenhouse gases like carbon dioxide (CO2) in the atmosphere. Greenhouse gases trap the heat in the atmosphere making the planet warmer. Hence there is a need to identify areas that emit CO2 gases. GIS offers a highly flexible, easily updateable database and display tool that facilitates the spatial analyses [1] required to identify such areas.

**Ideal**

The CO2 emission rate should be monitored continuously and make sure it doesn’t reach a high level. This will help to reduce global warming. We also need to determine the main sources of CO2 so that measure can be taken to reduce it.

**Reality**

However, in the United States there are states that release CO2 at a very high amount. This has made US 2nd in the world in the world in terms of CO2 emission. In 2007 United States recorded an emission rate of 6.13 million metric tons of CO2 [10]. Ever since then this number has been reduced but not by a significant amount. There is a need to keep a check on these number before it gets too late.

**Consequences**

In response to this problem, we can use ArcGIS pro features and GIS principles to create visualizations that will help to determine such area and also indicating the level of CO2 emitted. We also need to determine the which sources of this emission so that efforts can be made to reduce this amount. This will significantly help to reduce global warming.

**2.2 Project Goals and Objectives**

The main goal of this project is to identify areas in the US where CO2 emission is the highest. In order to achieve this goal, we are going to complete the following objectives.

**Objective 1:** Collect past 10 years of data on CO2 emission in the United States. For this I’m going to make use of the following dataset.

<https://data.worldbank.org/indicator/EN.ATM.CO2E.KT?end=2016&start=2006&view=chart>

**Objective 2:** Perform spatial analysis in order to determine relationships, describe locations etc. Create visual maps to identify such areas.

**Objective 3:** Create an inset map of the area that emits the highest amount of CO2.

**2.3 Significance and potential benefits**This project can help determines which areas of United States have high levels of CO2 in the air. We will also be able to view the different coal mines and crude oil pipelines that are present throughout the United States. We will also be able to assign a color code for different areas on the map based on their CO2 level emission.

# **Literature Review**

Paper [2] talks about the use of GIS tools to estimate the effects of retail stores in the urban structure on overall CO2 emissions in the Oulu region Finland. Through this project they were able to identify areas in Oulu region where CO2 emission is highest and lowest based of the population. They created a CO2 map for the region which is able differentiate areas based on their CO2 value.

[5] This paper makes use of GIS techniques to quantify and map carbon sink and stock values of forest ecosystem. This project made use of GIS tools to create various data models for improving carbon sink and stock for local forest ecosystem.

# **Methodology**

1. **Dataset:**

The primary dataset that was used for this project was extracted from U.S. Energy Information Administration. This dataset consisted of data from 2006 till 2017. This data includes a measure that indicates the CO2 level for different states. Along with the above dataset we also have a shapefile for the US states. In order to make much more sense of the data we will be making use of United States shapefile for all the states. This will help us to perform spatial analysis and cluster the different region. Combining both of these datasets will provide context as well as help in verifying the data collected.

1. **Preprocessing:**

After all the data was downloaded, they were unzipped and placed in their respective directories. The data downloaded from U.S. Energy Information Administration consisted of a .csv file that consists of energy-related carbon dioxide emission by states from 2005 till 2017. In order to add the data from the csv files I first created a join between the csv and shapefile using the state name as a foreign key.

The .csv consisted of data from 2006 till 2017. Two addition field were created in the csv file uding excels SUM and AVERAGE function I calculated the sum and average CO2 level for the past 10 years. These fields will be used to determine which state emits CO2 in a higher amount. We can also use this dataset to create a visualization of the CO2 emission rate for each year from 2005-2016 [12]. These were all the modifications done in the csv file.

Since the shapefiles didn’t have any relevant data connected to CO2 present in them there was a need to add it in the dataset. Using the data collected from [12]. I extracted data for the different states of US from 2005 till 2016. In order to add the .csv files data in the shapefiles a join operation was performed. Using the state names the data was added in the shapefile. There was a need to edit the .csv in order to do so a feature table was extracted from the .csv file and named CO2\_GIS. This enabled me to edit the names of the fields. Since the state’s names were similar in both the files it was used as a foreign key reference. After the CO2 attributes were added in the shapefile, they were used to create a map to represent the CO2 emission level on the map.

1. **Analysis:**

For this project we are going to make use of the shapefile for USA states and Co2.csv. First both of these files were combined by adding a join between them. The id and state fields were used to create a relationship between both the files. Along with those fields the dataset also contained information regarding CO2 emission for each state from the year 2005-2016. Fig 1, 2 and 3 show the CO2 emission map for the years 2016, 2015, and 2014.

Using ArcGIS pros symbology function, we were able classify the different states on the map using its gradually changing color property. There are in total 5 classes which are using to represent different areas on the map. From figure 6 it can be seen that white color represents areas with low CO2 level and dark green represents areas with higher level of CO2. All of these features were extracted and stored in the geodatabase which can be viewed as layers in the ArcGIS Pro.

**2016**

**A picture containing text

Description automatically generated**

**Map

Description automatically generated with low confidence**

Fig 1: CO2 emission map of 2016

**2015**

**A picture containing diagram

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Fig 2: CO2 emission map of 2015

**2014**

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Fig 3: CO2 emission map of 2014

Fig 4 shows the average CO2 emission rate from 2005 till 2016. This map also includes location of coal mines and crude oil pipeline that are located all over United States. There are in total 8 coal mines that are located in Texas which can be seen in figure 5.

Diagram

Description automatically generated with low confidence

Fig 4: Map indicating which state emits the highest level of CO2. The orange line indicates

the crude oil pipelines and yellow dots indicate coal mines.

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Description automatically generated

Fig 5: Pipelines and coal mines that pass through and are located in Texas

Text

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Fig 6: Map Legend

An inset map was created using ArcGIS pro. The inset map shows a view of Texas. Texas is dark green in color indicating it emits CO2 at a high amount. The inset maps show a particular area on a map at a larger scale compared to the main map. It mainly is used to shows a particular area of the main map in a much larger view in order to see some feature more clearly. In this case Texas in made larger to view it more clearly. The blue dots on the map indicate the coal mine present in the state of Texas. The inset map was created by adding a map frame in the layout page. After adding the map frame, we can get a view of the map created. Clicking on the activate button opens a view where we are able to navigate along the map and see a particular location. We can expand over a particular area which will help to view some of it features more noticeable for example roads, indicators etc. There is also a compass on the map and a scale. The legends on the map includes yellow dots that indicate coal mines present around US, blue dots indicating coal mine that are present in Texas, Crude Oil pipelines, states shape file and the 5 classes indicating areas on the map that emit the highest amount of CO2.

# **Result**

Map

Description automatically generated

Fig 7: CO2 emission map of United States

# **Conlcusion**

From Fig 2 we can see that Texas emits the highest amount of CO2 followed by Florida, California, Illinois, Louisiana, Pennsylvania. States like Alaska, South Dakota, Nevada has the lowest CO2 emission rate. The area which are dark green are those areas where CO2 concentration is the highest. From Fig 3 we can see that there are a lot of crude oil pipelines that pass-through Texas as compared to other states. From figure 4, 5 and 6 it can be seen that the CO2 emission levels of Texas has been consistently high. Indicating that proper measures need to be taken to bring the level down to a minimum value.

# **Future Work**

If this project were to be continued in the future, I would like to incorporate more features in this model which will help to further classify facilities on the map based on their CO2 emission levels. We can even generate a CO2 footprint map for US that will us a much better overview of the emission rate. We can also add more data in the form of layers that will have more distinct features to use for classification. Apart from these statistical analysis needs to be performed to verify the results. Since we have the data for past 10 years, we can create a temporal trend to see the changes that have taken place in the CO2 levels over the years. For example, power plants in the United States are responsible for CO2 pollution. Creating a map that can visualize the CO2 gases in the atmosphere can help give a much-detailed view of the areas affected. We can make use of raster dataset in this case.

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