VISUALISING GLOBAL SOCIOECONOMIC TRENDS IN D3

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1 Introduction

This report presents a visualisation of an ensemble of datasets compiled by NASA's Socioeconomic Data And Applications Center (SEDAC) to visualise the correlation between socioeconomic and environmental performance (current and predicted) based scenarios defined by the Intergovernmental Panel on Climate Change (IPCC).

This visualisation aims to put sustainable consideration and wealth into perspective in different countries, with an example of socioeconomic impact: crop production, directly correlated to life prices and purchasing power.

Questions one might ask oneself when using this visualisation are, for instance:

- How correlated is wealth to environmental concerns?
- How are emissions distributed worldwide?
- How have environmental concerns evolved?
- Are wealthy countries very likely to be impacted by food shortage?
- Are highly emitting countries likely to be impacted by food shortage?
- What is the variation of food production depending on the emission path taken globally?

The data presented takes into account the years from 1990 to 2100 in all countries. The indicators displayed are wealth per capita, greenhouse gas emissions, environmental performance indices and crop production.

The live version of our visualisations can be found at abhaydmathur.github.io/sedac-vis, while a condensed version of this documentation along with a demonstration for the former's usage can be found here.

2 Data

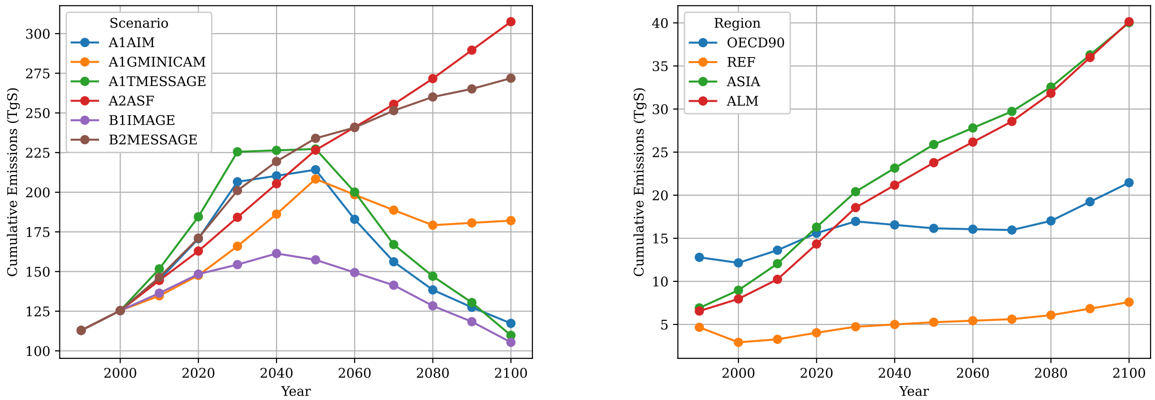
2.1 Gridded Emissions

We consider global gridded emissions for reactive greenhouse gases, as covered in the Intergovernmental Panel on Climate Change (IPCC) Special Report [1]. Emissions for every unit (`longitude`, `latitude`) (measured in TgS) have been projected every ten years, from 1990 to 2100.

The dataset covers six scenarios, as Table 1 explains. A representative summary of the dataset, which shows the variables involved and expected trends, can be found in Figure 2.

2.1.1 Preprocessing

Preprocessing for the gridded emissions involved mapping coordinates to their `closest_city`, and `country` and grouping them by the latter. This was accomplished with a Python script using the `reverse_geocoder` and `pycountry` libraries.



(a) CH4 Emissions in Asia

(b) NOx Emissions in Scenario A2ASF

Figure 1: A Summary Representation of the 1x1 Gridded Emissions dataset. Part (a) shows the predicted emission levels for Methane (CH4) in Asia for all scenarios [Table 1] in consideration, while Part (b) shows the predicted emissions of Nitrogen Oxides (NOx) in different regions (North America + Western Europe, Central & Eastern Europe, Asia and Africa & Latin America) in scenario A2ASF (High Population Growth, Regionalism, Technological Development, Regional Inequality)

2.2 Environmental Performance Indices

The Environmental Performance Index (EPI) is a tool developed by the Yale Center for Environmental Law and Policy (YCELP) and the Center for International Earth Science Information Network (CIESIN) at Columbia University [2, 3]. The EPI is designed to assess and rank the environmental performance of countries worldwide. It provides a quantitative analysis of a country's environmental policies and outcomes across various indicators.

The EPI is calculated based on a set of performance indicators that fall into two broad categories: environmental health and ecosystem vitality. These categories are further divided into sub-indicators, creating a comprehensive framework for evaluating a country's environmental performance. The specific indicators may vary across different editions of the EPI and may include more than 40 indexes, but common examples include:

1. Climate Change Indicators:
   - CO2 Growth Rate
   - Black Carbon Growth Rate
   - CH4 Growth Rate
   - F-Gas Growth Rate

Emission Scenario	**Scenario Assumptions**	**Model Parameters**
A1B-AIM	Rapid economic growth, urbanisation, industrialisation, balanced use of fossil fuels, biomass	economy, climate, land use
A2-ASF	Rapid economic growth, urbanisation, industrialisation, strong emphasis on fossil fuels	economy, energy, environment
B1-IMAGE	Moderate economic growth, urbanisation industrialisation, shift to clean energy sources and greater emphasis on sustainable development	atmosphere, ocean, land, human activities
B2-MESSAGE	moderate economic growth, urbanisation, industrialisation, focus on sustainable development	energy, climate, economy
A1G-MiniCAM	Low rate of population growth, heavy reliance on fossil fuels	atmosphere, ocean, land, ice
A1T-MESSAGE	Rapid economic and technological advancement, strong focus on sustainable development	energy, climate, economy

Table 1: Scenarios for 1x1 Gridded Reactive Gase Emissions

2. Environmental Health Indicators:
   - Air quality
   - Water and sanitation
   - Ambient particulate matter pollution
   - Recycling Rates
3. Ecosystem Vitality Indicators:
   - Biodiversity and habitat
   - Fisheries
   - Tree Cover Loss
   - Health impacts Agriculture

We have taken four sub-indicators with high weights in EPI and created plots that illustrate the dependency between sub-indicators and the country's GDP. More information about selected sub-indicators:

1. *CDA: CO2 Growth Rate*
   The CO2 growth rate is calculated as the average annual increase or decrease in raw carbon dioxide emissions over 1995–2022. It is then adjusted for economic trends to isolate change due to policy rather than economic fluctuation.
2. *PMD: Ambient Particulate Matter Pollution*
   Measure $\mathrm{PM}_{2.5}$ exposure using the number of age-standardised disability-adjusted life-years lost per 100,000 persons (DALY rate) due to exposure to fine air particulate matter smaller than 2.5 micrometers ($PM_{2.5}$).
3. *TCL: Tree Cover Loss*
   Quantify tree cover loss by constructing a five-year moving average of the percentage of forest lost from the extent of forest cover in the reference year 2000. We define a forest as any land area with over 30% canopy cover.
4. *REC: Recycling Rates*
   Measure recycling rates as the proportion of post-consumer recyclable materials (glass, plastic, paper, and metal) that are recycled.

All these data are available from 1995 to 2022. It is normalised with minimum value 0 and maximum value 100, and therefore does not require pre-processing.

2.3 Gross Domestic Product per Capita

Each country's per capita GDP values (in current USD) were obtained from the World Bank DataBank [4]. The dataset spans from 1973 to 2022 and was clipped from 1995 to 2020 for our visualisations.

2.4 Effects of Climate Change on Global Food Production

This dataset [5, 6] presents the predicted productions of wheat, rice and maize under 7 Special Report on Emissions Scenarios (SRES), which describe seven plausible futures with different emission trajectories as described below. These scenarios have been designed by considering different socioeconomic and technological developments. Some of these are:

- Various speeds of carbon removal technologies developments
- Evolutions in the global energy mix
- The speed of population and economic growth
- The attention given to sustainable and social issues

All of these impact the evolution of emissions over the 21st century and thus crop production. Some of these scenarios [Table 2] coincide with the ones used in the emissions display. However, we have decided not to merge them to avoid mixing or losing information since the hypotheses taken in each case are different.

The available information considers 'current' production averaged between 2000 and 2006 and gives the expected variations compared to this value for years 2020, 2050 and 2080 depending on the trajectory of greenhouse gas emissions.

Scenario	Description
AF1	"All fossil fuels" scenario. It considers a world with rapid economic and population growth, peaking mid-century and decreasing after; the rapid introduction of new and more efficient technologies; and a fossil fuel-intensive energy mix.
A2a	This scenario considers a nationally or regionally oriented development, leading to fragmented economic and technological growth as well as a steadily growing population.
A2b	Similar to A2a but considering a more rapid technological development leading to a less carbon-emitting scenario.
A2c	Similar to A2a and A2b, but with greater emphasis on social sustainability.
B1a	Considers the same population evolution as scenario A1 but a rapid economic evolution towards service and information; the development of clean technologies; and an emphasis on social sustainability.
B2a	A scenario focused on local solutions, an intermediate level of development, less rapid and more diverse technological development than previous scenarios, as well as a balanced energy mix.
B2b	Similar to B2a, but with more emphasis on social and economic sustainability.

Table 2: SRES Scenarios Considered for Predicting Crop Yield Data

2.4.1 Preprocessing

In the raw data, the crop evolution is described in terms of absolute variation and percentage. The absolute value used in our visualisation has thus been computed using the current production and the absolute predicted variation. Some country names have also been altered in order to match those used in the other datasets, for example, the emissions data uses the name 'United States of America' while the food data used 'United States'.

3 Design choices

The visualisation is composed of four sections:

- The navigation section, allowing the user to select his country and date of interest
- Greenhouse gas emissions
- Environmental Performance Indices compared to GDP per capita
- Crop production and predictions depending on the IPCC scenario

Please refer to our information page for animated depictions of each section.

3.1 Navigation section

The aim of this section is for the user to select their country and period of interest. It does not contain data, thus allowing the use of a globe rather than a map. The selection done by the user updates the other visualisations.

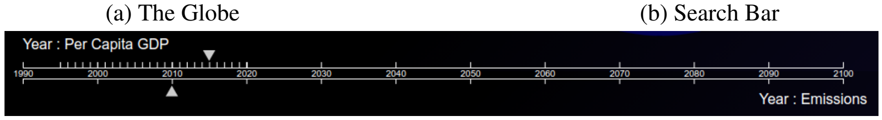
3.1.1 Interactive 3D Globe

This globe [Fig 2a] allows the user to select his country of interest, by double-clicking on the interactive globe. We have decided to use this visualisation because it provides a satisfying user experience but does not hide any information, since this map in not displaying data. The selected country is highlighted in yellow.

Rotation from one country to the other is not trivial since the orthographic projection for each country does not have a linear transform between two orientations of the globe. Therefore, to make the transformations appear like those of an actual globe, we use a tweening loop which interpolates between the current and desired orientation of the globe and rotates iteratively.

(a) The Globe

(b) Search Bar



(c) The Timeline

Figure 2: The Navigation Section. Users can drag their cursor to rotate the globe (a) and double click to select the country, or simply enter its name in the searchbox (b). The two sliders on the timeline (c) are used to set the year for GDP and Emissions (2015 and 2010 respectively, in this image).

3.1.2 Adaptive search bar

The user can also use a search bar [Fig 2b] to find a specific country by name.

The search bar proposes countries using the first letters provided by the user and, once selected, highlights the chosen country and rotates the globe accordingly. This functionality has been added in order to allow the user to select countries that might be tricky to double-click on due to their size, or to look for countries whose location he is unaware of.

The search bar executes a substring search on the list of all countries and provides a filtered list of possible countries with that substring when the length of this filtered list is less than 20. Pressing enter automatically selects the first element of the filtered list.

3.1.3 Timescale

The timeline [Fig 2c] constitutes a time axis from 1990 to 2100, with ticks every ten years for the entire range (pertinent to Reactive Gas Emissions) and for every year from 1995 to 2020, the range of Per Capita GDP (pertinent to the choropleth and EPI graphs).

The two sliders can be adjusted independently to select the year for their corresponding data.

3.2 Gridded Emissions

The aim of this visualisation is to put into perspective the localisation and amount of emissions with the wealth of countries. We, therefore, represent emissions through a bubble map using a chloropleth [Fig 3] with each country's GDP per capita in the backdrop.

The bubble map effectively communicates the spatial distribution and intensity of emissions, allowing for the identification of emission hotspots and patterns (the tooltips on the bubble map provide precise locations and degrees of emissions in TsG). This spatial context aids in pinpointing regions with disproportionate contributions to global emissions. Simultaneously, the juxtaposition with a choropleth backdrop, depicting GDP per capita, facilitates the assessment of the environmental impact relative to the economic strength of each country.

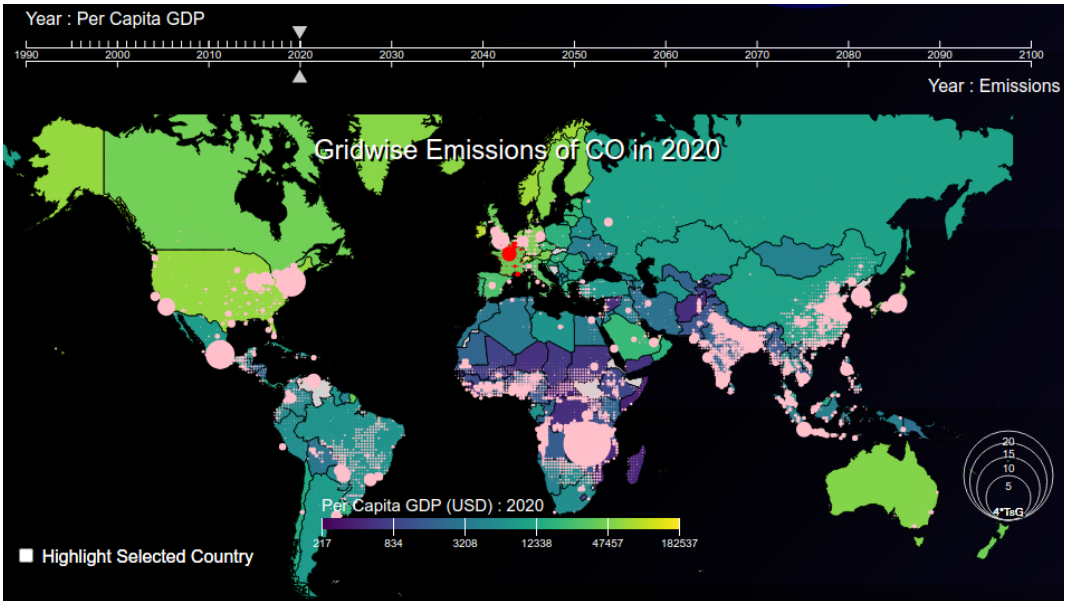


Figure 3: Chloropleth of Per Capita GDP in 2020 with global Carbon Monoxide (CO) emissions for 2020 in the bubble map. Bubbles are red for the selected country (France) and pink otherwise.

3.2.1 Visualisation update

The map is updated with the use of the previous navigation section: when a country is selected, it zooms on it and displays its area colour and emissions colour in bright (when `Highlight Selected Country` is enabled), helping the user focus on the region of interest and find country-specific information. However, it is possible to zoom out to compare it with other regions of the globe.

The transformation and scale for updating the map are determined by the bounds of the selected country. However, this poses some challenges for nations with territories on both sides of the international date line (USA, Russia) - since the map's projection is two-dimensional and wrapping around the map doesn't prove optimal for the visualisation. Therefore, the transformations for such nations have been set by using some reference nations and may lead to distortions for some screen sizes.

3.2.2 GDP per capita

We have decided to colour-encode the map with respect to country wealth. Since this implies that areas are encoded, the perception of the value might be influenced by the size of the country. In order to prevent this, we have decided to normalise our data with respect to country size using GDP per capita rather than GDP to colour code the map. The encoding legend is displayed below the map.

We use a log scale on the per capita GDP values to be able to observe differences better and apply the sequential `d3.interpolateViridis` colour scheme for the choropleth.

3.2.3 Emissions

The map displays the locations and the amount of a selected gas. This is encoded with positioning and size of circles on the map, allowing the user to spot regions of maximal intensity when zooming out and to have a fine grain analysis when zooming in.

3.2.4 Selectors

The user can select the type of scenario he wishes to see, rather than displaying all the scenarios on one map. This choice has been made to prevent confusion and overflow of information. It is also possible for the user to select the type of emissions he is interested in using a scroll down menu above the map in order to have a more precise understanding. Since the scenarios considered in this dataset are not the same as those used in the crop production visualisation, we have decided not to connect them together.

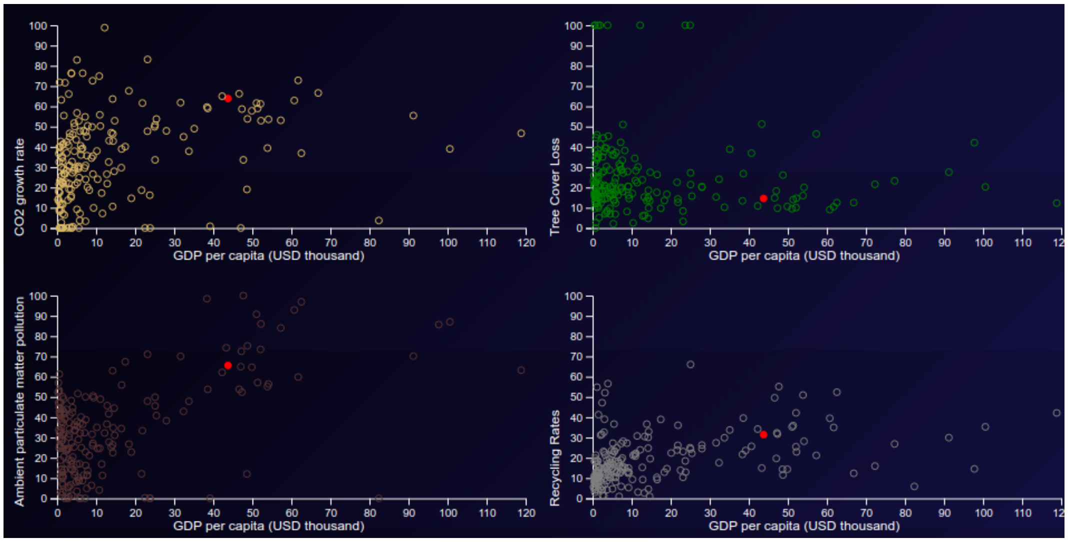


Figure 4: Environmental Performance Indices, 2011. The four graphs show each nation's performance score against its per capita GDP, with the selected country (France) highlighted with a red marker. Tooltips display the datum's corresponding country.

3.3 Environmental Performance Indices

The four plots [Fig 4] model the relation between to environmental concerns and country wealth.

3.3.1 Visualisation update

The selected country is displayed in a red fill to stand out from other countries using the 'odd-one-out' visual technique. The information is updated using the timescale selected by the user, which allows him to follow the evolution of the indicators over time.

3.3.2 Data points

If a user wants to compare the selected country to other points, it is possible to see what the other points are by hovering over them to see their name. In this way, the user is able to know which country to select in the navigation section if he wants to have more information on a specific point of interest.

3.3.3 Data representation

In order to be in line with the information displayed on the emissions map, the wealth indicator used is also GDP per capita so that the user is not confused with the scales. We had at first envisioned to display the indicators on the same graph using different shapes and a normalised scale, however this resulted in reduced readability and occluded information, and we have thus decided to use multiple graphs.

3.4 Crop Production

This graph displays the current and predicted production of wheat, maize and rice in the coming years depending on the greenhouse gases emissions' trajectory.

3.4.1 Visualisation update

The graph depicts the predictions for the selected country and is updated accordingly. We have decided not to make the visualisation change with the timescale since it depicts predictions which do not vary with the date, and we only have information for 2000-2006, 2020, 2050 and 2080. The scale of production is automatically updated to the selected country so that the data points are as spread out as possible on the graph. This is helpful since countries have very different orders of magnitude in crop production but also in between crops 5.

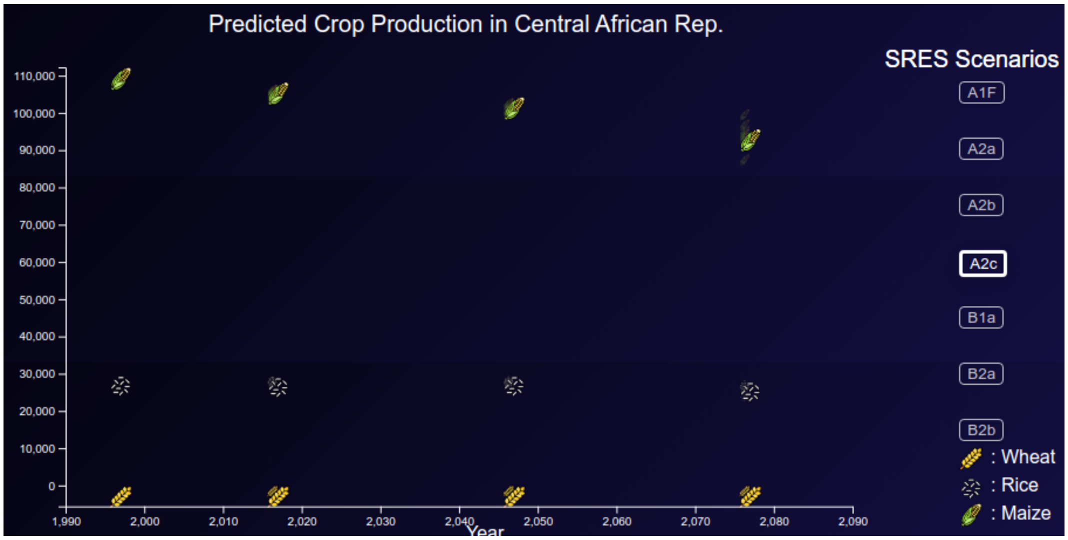


Figure 5: Predicted Crop Production. Customised icons represent the three crops. SRES Scenarios can be chosen from the buttons on the right.

3.4.2 Data representation

The graph displays data points using icons associated with and representing each crop. Since the graph is not densely populated, the icons are easy to distinguish from one another and allow for a more straightforward reading of the graph rather than having to use a legend.

3.4.3 SRES Scenarios

At first, all the scenarios are displayed on the graph so that the user is able to compare them. However, since the icons can be quite close together depending on the scale, it is possible to use the side buttons to select a scenario of interest. Clicking on this bottom displays the selected production values in bigger, while the opacity of other icons fades out in order to let the user still have an idea of where the other scenarios are positioned but make the selected one stand out.

3.4.4 Technical choices

This section has been created using d3, and the icons were selected from Flaticon. A general function creates the groups where the country data is stored, along with the buttons and the initial graph visualisation. A dedicated function manages button usage, and another one deals with country update by emptying all the groups in the svg canvas and relaunching the display function with the new country information.[7]

4 Conclusions

This visualisation displays an ensemble of socioeconomic and environmental indicators and puts them into perspective with environmental impact. It allows the user to interact with the data to highlight information according to his interest and draw visual conclusions by helping him better understand the data. It is designed to be user-friendly and interactive, providing a pleasurable experience.

References

[1] Intergovernmental Panel on Climate Change-IPCC,. IPCC special report on emissions scenarios (SRES) 1x1 degree gridded emissions dataset, 2000.

[2] Yale Center for Environmental Law + Policy-YCELP - Yale University, and Center for International Earth Science Information Network-CIESIN - Columbia University,. 2022 environmental performance index (EPI), 2022.

[3] M J Wolf, J W Emerson, D C Etsy, Z A Wendling, and Et al. Environmental performance index 2022. Technical report, Yale Center for Environmental Law and Policy, New Haven, CT, 2022.

[4] The World Bank. World Development Indicators. databank.worldbank.org, 2022.

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[7] FLATICON (Available: www.flaticon.com) Last Accessed December 22, 2023.