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Topographic and thematic (in)visibility of Small Island Developing States in a world map

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ABSTRACT

Many world maps visualize global data to represent the statistical and spatial relationships among countries. These maps are typically printed in reports or displayed online at a small scale. At such scale, small nations are difficult to perceive or even disappear, as is often the case for Small Island Developing States (SIDS), a group of more than fifty island states designated by the United Nations for their social, economic and environmental vulnerabilities. While the United Nations aims to address the social, economic and environmental challenges world-wide through the Sustainable Development Goals (SDGs), SIDS can be missing from maps presenting SDG indicator data. This constitutes five percent of the world population missing from maps. We propose maps and visual representations to address the perceptibility of SIDS and the availability of their indicator data to offer a more complete visualization of the status towards achieving the SDGs.

1. Introduction

Facing extreme social, economic and environmental challenges in the twenty-first century, the Sustainable Development Goals (SDGs) were established by the United Nations member states to create a peaceful and prosperous existence for all people and the planet by 2030. The 17 SDGs are evaluated by 169 targets and measured by 232 indicators. Maps visualizing SDG indicator data are necessarily generalized to fit print and online formats. During the generalization process, small areas often become difficult to discern or disappear. This in itself is not the problem; however, when it affects the ability to see the indicator values for small nations or states, it gets worrisome.

When global data are visualized in small-scale maps, the challenge to see small areas translates to the challenge to see values for small nations or states. This can affect Small Island Developing States (SIDS), which are small islands (and a few coastal countries) recognized by the United Nations for their social, economic and environmental vulnerabilities. Compared to larger states, the coastline exposure of SIDS relative to their geographic size increases their environmental vulnerability, and in some instances their isolation from neighboring populations reduces their coping capacity. Given the relative small size of their population, SIDS experience high costs per capita for infrastructure and services that could help predict, prevent and respond to disasters (Pelling & Uitto, 2001). It is difficult for national statistics offices to collect data on SIDS due to the specialization and budget required (PARIS21, 2014). This results in limited statistical data for SIDS, such as those used by SDG indicators. According to estimates by the Alliance of Small Island States, which advocates for SIDS within the UN system, this group of states comprises five percent of the global population (AOSIS, 2018). Yet their topographic and thematic representation is a seemingly invisible problem in many small-scale world maps.

We propose ways to enhance the visualization of SIDS in world maps displaying Sustainable Development Goal indicator data. Our solutions confront both the geographic and thematic representation of SIDS. A base map was developed by considering projections and symbolization specific to the needs of SIDS in small-scale maps and evaluating these solutions through two focus groups and an online survey. Here we present two visualization techniques, one static (Main Map) and one interactive, to recommend cartographic practices to illuminate SIDS at a global scale and address the visualization of missing indicator data.

1.1. SIDS and SDG indicator data

The SIDS identified in the maps were cross-referenced between those listed on the UN Sustainable Development Goals Knowledge Platform and those defined by the UN Statistics Division, resulting in 52 SIDS contained in both at the time of writing in mid-year 2018 (Figure 1) (DESA - UN, 2018; UNSD, 2018).
Of the 232 SDG indicators, most measure a specific variable in relation to a proportion of (sub)population and are categorized in three tiers based on availability of data (Kraak et al., 2018). Tier I indicators have data available for at least 50 percent of the population in each UN region. Tier II indicators contain data less recently and consistently available for countries. Tier III indicators are in progress of being established and standardized worldwide. Of the 232 indicators, 93 were Tier I (40 percent), 72 were Tier II (31 percent) and 62 were Tier III (27 percent); five were a combination of tiers (two percent) at the time of writing in mid-year 2018.

The UN database of SDG indicators (https://unstats.un.org/sdgs/indicators/database) identifies SIDS, yet data are often missing for these states, even in Tier I indicators. Researchers note missing data is a common problem for SIDS, and in the creation of the SDG Index and Dashboards Report, 25 SIDS were omitted completely from analysis due to missing data (Nurse et al., 2014; Sachs et al., 2017). For this research project, we selected SDG Indicator 1.1.1 Proportion of population below the international poverty line (Goal 1, Target 1). This indicator contained data for 138 of the 193 member states, including 21 of 52 SIDS, making it representative of the available (and missing) data for SIDS in Tier I SDG indicators at the time of download in mid-year 2018. While Indicator 1.1.1 has been updated, it offers less data for SIDS and other member states, leading us to use the prior dataset for the Main Map.

2. Visualization approaches and design considerations

SDG Indicator 1.1.1 is proportional (percentage) and therefore best visualized in a choropleth map. Using ESRI ArcGIS Desktop and Adobe Illustrator, the Main Map was designed for printing on A3 paper by establishing the base map and then determining the visual representation of the SIDS.

2.1. Base map

One of the first items to consider when designing a small-scale world map is the map projection. Equal area projections are widely considered ideal for visualizing statistical data in choropleth maps. Among equal area projections there are varying preferences, though common projections used by atlases include Mollweide and Eckert IV (Figure 2) (Savric et al., 2015). An alternative to these projections is the Interrupted Goode Homolosine projection (Figure 2). It is an equal area composite projection of the Sinusoidal projection in a band 40° 44’ north and south of the equator and the Mollweide projection in the remaining latitudes. When it is focused on water, as with Interrupted Goode Homolosine (Ocean), it is characteristically centered in the Pacific Ocean and splits landmasses using three lobes, of which the left and right focus on the Indian and Atlantic Oceans respectively. This allows one to concentrate on the SIDS in the three oceans (and the Caribbean Sea).

Given limited guidance from prior research specific to user preferences of projections for choropleth maps or the visualization of SIDS, a study was conducted to determine a preferred base map. During this process two focus groups of geoinformation scientists and cartographers discussed proposed solutions to visualize SIDS in choropleth world maps (Gosling-Goldsmith, 2018). These included continuous and interrupted projections, though compared to other studies of
projections, the shape of the projections and their graticules were not emphasized as these are traditionally omitted in choropleth maps. Based on responses from focus group participants, the Interrupted Goode Homolosine (Ocean) projection was selected and evaluated in an online survey by a broader audience of cartographers, map users and international professionals. Correctness and satisfaction in using the map to identify the choropleth value of SIDS was evaluated. At the end of the survey an open field for comments was provided. Results from the focus groups and online evaluation informed the Main Map shared here (Gosling-Goldsmith, 2018).

The Interrupted Goode Homolosine (Ocean) projection was selected for the Main Map. While it is suitable for statistical data and emphasizes SIDS regions, some focus group and online survey participants noted disorientation when looking at the Interrupted Goode Homolosine (Ocean) projection (Gosling-Goldsmith, 2018). Most participants were predominately from North America and Europe, which may have normalized seeing world maps centered at or near the prime meridian. It is also possible that splitting the landmasses added to disorientation. To aid in orientation, non-traditional choropleth world map techniques were applied to the map, such as coloring the oceans in light blue, labeling the oceans and adding graticules.

2.2. Graphic and geographic representation of SIDS

In the Main Map, three classes were established for SDG Indicator 1.1.1 Proportion of population below the international poverty line, plus a fourth category of missing data. Limiting the classes simplified the identification of values in small symbols. Three classes of color values permits selectivity in point symbols, which allows the viewer to globally see groups of point data (Bertin, 1983).

Small Island Developing States are distributed in four main regions: the Atlantic Ocean, Caribbean Sea, Indian Ocean and Pacific Ocean (including the South China Sea). SIDS vary in their geographic composition from one island to many islands, such as the Seychelles, which has 115 islands, or the Solomon Islands which has nearly 1,000 (Everest-Phillips, 2014). At a world map scale (1:100,000,000) on a standard A3 printed page, the islands in the Caribbean are densely clustered compared to the relative geographic distribution of islands in the Pacific or Indian Oceans. In order to identify the geographic location of SIDS, a compact graphic solution for their representation and identification was required.

Two graphic representations were reviewed for their potential to mark and identify the location of SIDS, ISO-alpha3 codes and circular point symbols. ISO-alpha3 codes are three letter codes identifying each state that are maintained by the International Organization for Standardization. ISO-alpha3 codes provide thematic representation through the color of the letters representing the attribute value, as well as topographic identification in one symbol. Similar to three letter airport codes, some ISO-alpha3 codes are remarkably easy to decipher while others are less logically linked by the uninitiated to the name of the state. Circular point symbols are compact symbols with ‘smooth visual’ properties relative to other geometric symbols such as triangles and squares (Krygier & Wood, 2005, p. 215). Circular point symbols were preferred to ISO-alpha3 codes by focus group participants and results from the online survey suggest the circular shape was an intuitive symbolic solution (Gosling-Goldsmith, 2018). Circular point symbols were used in the Main Map.

The Natural Earth 1:110 m shapefile was the base boundary file for this map. The Natural Earth 1:50 m

Figure 2. Mollweide, Eckert IV and Interrupted Goode Homolosine (Ocean) offer equal area projections.
shapefile and Tiny Country Points shapefile completed the SIDS topographic dataset to identify the location of smaller islands in the Caribbean and Tuvalu respectively. A circular point symbol was placed in the centroid of each Small Island Developing State that would otherwise be difficult to perceive at this scale. This provided a consistent graphic treatment for SIDS. Given the density of islands in the Caribbean, the point symbols were displaced, and leader lines identified the location of SIDS. This solution avoided overlapping symbols in the Caribbean for an unobstructed view of all SIDS in the region. Toponyms identified all Small Island Developing States in the Main Map.

2.3. Symbolization of SIDS

The points representing SIDS enhance their visibility, and the symmetry of the point symbols and the applied drop shadows further distinguish them from larger national landmasses in the Main Map. The graphic treatment of missing SIDS data could be modified depending on the proportion of available and unavailable data and how much visual weight is desired for missing data. These visualization approaches to missing data could be extended to non-island states as well, especially given the current status of available SDG indicator data world-wide.

2.4. Missing data of SIDS

Given the small size of point symbols representing SIDS and the prevalence of missing attribute data, alternative graphic treatments of missing data were explored (Robinson, 2019). The missing data of SIDS could be differentiated from available data by using visual variables applied to the fill of the symbol, such as texture, saturation, blur, hue or value (Figure 3) or changing the value or hue of the symbol’s outline (Figure 4) (Bertin, 1981, 1983; MacEachren, 1992; Morrison, 1974). While most solutions proposed by Robinson are included here, it is interesting to note that the blank solution, omitting a symbol where there is not information, would not be advisable in this scenario due to the invisibility problem of the SIDS: the geographic locations of the SIDS are not known to most map readers, making it difficult to notice and identify missing SIDS.

Fill options experiment with the concept of missing or unknown values by using white or dark fills in empty and desaturated, dark value solutions. Texture, saturation and hue provide varying visual contrasts to the graphical representation of available data. Similarly, in the proposed outline treatments, shadow, hue and darker value differentiate data availability. In both categories, solutions such as blur (fill) and lighter value (outline) make the point symbols optically recede to the viewer, working with ‘visual metaphors’ as

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**Visualizing missing data**

**Point symbols (fill)**

| Three-class color scale | No data |
|-------------------------|---------|
| Empty                   |         |
| Texture*                |         |
| Saturation*             |         |
| Blur*                   |         |
| Hue*                    |         |
| Desaturated, dark value |         |

*Mentioned or illustrated in Robinson (2019).*

**Figure 3.** Visual variables applied to the fill of point symbols representing missing data.

**Visualizing missing data**

**Point symbols (outline)**

| Three-class color scale | No data |
|-------------------------|---------|
| Shadow*                 |         |
| Lighter value           |         |
| Hue                     |         |
| Darker value            |         |
| Drop shadow*            |         |
| Drop shadow and shape   |         |

*Mentioned or illustrated in Robinson (2019).*

**Figure 4.** Visual variables applied to the outline of point symbols representing missing data.
discussed by Robinson (2019). Another outline solution applies a drop shadow to the inner circumference of the circle to create the appearance of unavailable data as missing and below the page, while the drop shadow applied to the outer edge of the three-class color scale point symbols creates a three-dimensional effect of data available and above the page.

Ultimately, the Main Map applied an additional visual variable, shape, to further distinguish available and unavailable data as shown in the last option in Figure 4. While selectivity between shapes, such as circle and squares is not possible, changing the symbol used to represent the points of available and missing data further differentiates available and unavailable data at small point sizes (Bertin, 1981).

3. Interactive visualization

To address potential projection and orientation preferences in the Main Map, an interactive version (https://gip-itc-universitytwente.github.io/SIDS/) was developed in D3 (Appendix A) (Calisto, 2018). This allows users to switch between three equal area projections: Interrupted Goode Homolosine (Ocean), Eckert IV and Mollweide. Eckert IV and Mollweide projections were included because these continuous, equal area projections were among the top projections preferred among cartographers and map readers due to the shape of the projections and their graticules (Savric et al., 2015).

The movable central meridian provides a dynamic global view of indicator data. The user can adjust the central meridian to rotate and control the central focus of the map. Preliminary results from an online survey of international participants suggest that users prefer to center the map either on the prime meridian or on their home country in the interactive visualization, though further evaluation is required.

The interactive version uses circular point symbols to identify the location of SIDS, including those missing data. The SIDS in the Caribbean overlap at this scale without leader lines, making is graphically advantageous to use solely the circular shape of point symbols and avoid overlapping square edges or triangular points cluttering the Caribbean. To aid in the identification of SIDS, especially the overlapping point symbols in the Caribbean, a tool tip offers the ability to garner their value of interest.

While the interactive visualization solves some challenges found in the Main Map, it introduces other perceptibility considerations. In the design of the current interactive visualization, the overlapping point symbols representing SIDS data in the Caribbean would be improved by adding a magnifying lens or zoom functionality to the map. If zoom were included, an inset window might be added to maintain a global view.

An interactive map could offer the option to select a no data category to highlight the SIDS (and other states or nations) without data by using a differing hue to fill or outline the missing data. Therefore, the missing data would come to the fore when of interest and recede when not required.

Interactive options to customize world projections and central meridians could increase user satisfaction, though by offering individualized views, perspectives on global data may not be consistent. Keeping that in mind, the interactive visualization could be extended to permit the user to select other equal area projections and shift the focus of the world north and south. These enhancements might be implemented in an SDG dashboard to visualize each SDG indicator and connect global views to specific local data. Future evaluations would help understand the consequences if everyone uses a local view in discussing international data indicators, and possibly determine the extent to which global views might be effectively localized.

4. Conclusion

As we explore potential visualizations of global data inclusive of all states and nations, we confront the tension between projection preferences and customizable views. When maps center near or at the prime meridian, attention is drawn to the largest and centrally located countries in the map. Here we presented fundamental decisions required by those creating maps to represent global data, with special consideration to ensure SIDS are visible. The Main Map was developed to emphasize SIDS based on the selected projection, orientation and symbolization. When the Main Map was extended to an interactive version, alternative projections along with a moveable central meridian allows the user to select a preferred view of global data.

Since SDG indicator datasets are often incomplete, it is necessary to consider the visualization of available data as well as the graphic treatment of missing data. The invisible problem of the SIDS, in both their presence on the map and their missing data, was addressed in the proposed visualizations. These maps provide topographic and thematic visibility of SIDS, which contribute to a more complete view of our status towards reaching Sustainable Development Goals.

Software

Static maps were created using ESRI ArcGIS Desktop and Adobe Illustrator. Interactive visualizations are displayed using D3.

Disclosure statement

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

The Sustainable Development Goal dataset used in this visualization was accessed mid-year 2018 from the United Nations Global SDG Indicators Database, https://unstats.un.org/sdgs/indicators/database, Indicator 1.1.1.

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Appendix

Appendix A. Interactive map allows the user to change the projection and central meridian.