# SUSTAINABLE DEVELOPMENT GOALS AND UNCERTAINTY VISUALIZATION

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September 2018

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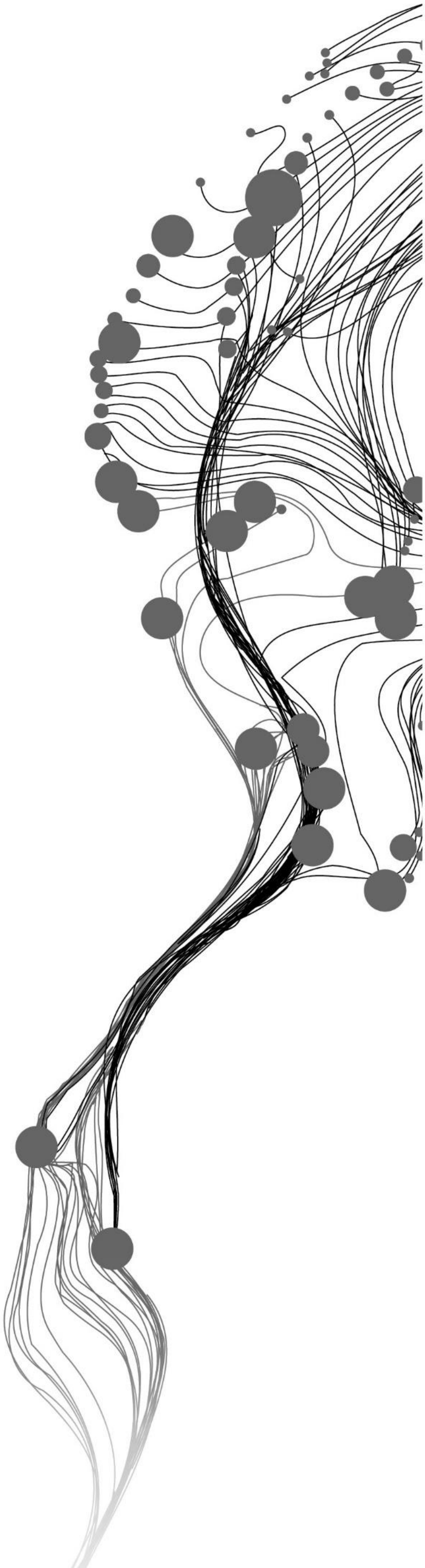

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# ABSTRACT

Small-scale thematic maps are used to represent world-wide data, yet small nations are difficult to discern or are omitted. This study offers alternative visualizations to enhance the perceptibility of small nation attribute values in choropleth maps using case studies of small island developing States and Sustainable Development Goals.

Small island developing States (SIDS) are a group of more than fifty states recognized by the United Nations for their social, economic and environmental vulnerabilities. United Nation member states collectively established Sustainable Development Goals (SDGs) in 2015 to interlink social, economic and environmental objectives to reach by 2030. There are 17 Sustainable Development Goals, which are comprised of 169 targets and 232 indicators. Sustainable Development Goal indicators are missing data for nations, including those of small island developing States.

This study proposed and evaluated five cartographic solutions to represent indicator data that was inclusive of small island developing States, making available and unavailable data perceptible for these States. These alternative designs were informed by an examination of Sustainable Developing Goal indicator data and inventories of ways to visualize small island developing States and incompleteness of data. Two focus groups provided feedback and narrowed the selection to one map, which was tested in an online survey. Survey participants had experience with small island developing States, worked in international organizations and/or had graduate-level degrees in a geographic-related science. While recommendations to improve the map are provided, more than half of the participants agree the design is appropriate to represent available and unavailable data of small island developing States.

**Keywords:** cartography, uncertainty, small island developing States (SIDS), Sustainable Development Goals (SDGs)

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# TABLE OF CONTENTS

# LIST OF FIGURES

# LIST OF TABLES

# 1. INTRODUCTION

## 1.1. Background

Geographic data is defined by space, attributes and time. Uncertainty of geographic information can be conceptualized using space, attributes and time in nine ways: accuracy/error, precision, completeness, consistency, lineage, currency/timing, credibility, subjectivity and interrelatedness (MacEachren et al., 2005; MacEachren, Roth, O'Brien, Swingley, & Gahegan, 2012; Thomson, Hetzler, MacEachren, Gahegan, & Pavel, 2005). As completeness of data is a component of certainty, this study defines incompleteness of data as contributing to uncertainty (Table 1). Incompleteness will be reviewed as gaps within the desired measurements of a dataset.

## 1.2. Research problem

Thematic choropleth world maps visualize global data. These maps are created at a small scale to display all countries on one surface and can be used to identify specific information about certain countries or "general information about spatial patterns" of world data (Slocum, McMater, Kessler, & Howard, 2009). However, due to scale and generalization, small nations are difficult to perceive or are omitted in choropleth world maps, making it challenging to visualize all national attribute values or notice if nations are missing data values in a world-wide context. Missing or imperceptible countries make choropleth world maps incomplete and contribute to the uncertainty of visualizing global data.

Table 1. Focus on the completeness aspect of geographic data in representation of uncertainty.

| Category | Space | Attributes | Time |
|---|---|---|---|
| Accuracy/error | Coordinates, buildings | Counts, magnitudes | +/- 1 day |
| Precision | 1 degree | Nearest 1000 | Once per day |
| Completeness | 20% cloud cover | 75% reporting | 5 samples for 100 |
| Consistency | From / for a place | Multiple classifiers | 5 say M; 2 say T |
| Lineage | # of input sources | Transformations | # of steps |
| Currency/timing | Age of maps | Census data | C = Tpresent - Tinfo |
| Credibility | Knowledge of place | U.S. analyst vs Informant | Reliability of model |
| Subjectivity | Local ←→ Outsider | Fact ←→ Guess | Expert ←→ Trainee |
| Interrelatedness | Source proximity | Same author | Time proximity |

Derived from MacEachren et al. (2012, Table 1).

### 1.3. Research objectives

This project proposes solutions for spatial incompleteness with considerations of attribute incompleteness through two connected cases: the imperceptibility of more than fifty nations designated by the United Nations as small island developing States (SIDS) in world maps and the incompleteness of United Nations Sustainable Development Goals indicators.

The research objective is to provide geographic visualizations to reveal the uncertainty of UN Sustainable Development Goal indicator data, focusing on the uncertainty's incompleteness aspect for location and attribute data. While increasing the perceptibility of small island developing States also increases the perceptibility of available and unavailable attribute data, this is a two-fold problem: (1) making the small island developing States more perceptible and (2) exploring ways the missing attribute data is represented. This study reviews both aspects but primarily addresses the perceptibility of small island developing States. In this regard, the solutions for the representation of small island developing States are reviewed and proposed in light of their promise for visualization of missing attribute data with the following objectives:

1. Develop inventory of methods on how to visualize:
    - Small island developing States
    - Incompleteness of data

2. Understand the nature of Sustainable Development Goal indicator data and how this might influence how one designs maps informing about both spatial and attribute incompleteness.

3. Evaluate the usability of proposed maps to address spatial incompleteness in choropleth world maps.

To accomplish these objectives, the following questions will be answered:

1. What visualization approaches exist to map small island developing States and incompleteness of data?

2. How can small island developing States be visualized in insightful ways using available Sustainable Development Goal indicator data?
    - What are the spatial characteristics of small island developing States?
    - What is the nature of Sustainable Development Goal indicator data?
    - What is the quality stamp for the tier categories of selected Sustainable Development Goal indicator(s) and what do these mean?

3. How do users interpret the visualization of small island developing States (and inclusion of missing attribute data)?
    - Which evaluation methods are to be used to understand which maps are preferred by users?
    - Which representations are preferred by users? Why?
    - Which representations communicate attribute values of small island developing States with clarity?

The study addresses these questions through a review of research and literature related to uncertainty visualization, small island developing States and Sustainable Development Goals in the second section. The third section outlines the methods used to define small island developing States and establishes prior geographic visualizations through a catalogue of uncertainty visualizations and representations of small island developing States. It also includes the steps to select a Sustainable Development Goal indicator and the process of creating maps and evaluating them. The results of the evaluations are presented and then discussed in the next sections, which are followed by the conclusion.

# 2. VISUALIZING UNCERTAINTY

## 2.1. Defining uncertainty

### 2.1.1. Spatial incompleteness

A map is a selected representation of reality. When a map visualizes the world at a small scale, spatial data must be generalized to accommodate the size constraints of the image surface on which it is represented. Generalization simplifies the spatial representation by removing details from the map (Dent, 1993; Kraak & Ormeling, 2003; Miller & Voskuil, 1964). Small islands on a small-scale world map may be difficult to distinguish or disappear in the generalization process. The potential to overlook small island nations due to scale and omission leads to incomplete visualization of global data.

Small Island Developing States (SIDS) are among the small nations that are difficult to perceive or missing from a world map. The United Nations designated the category of small island developing States (SIDS) in 1992, acknowledging the "social, economic and environmental vulnerabilities" of small islands at the UN Conference on Environment and Development (OHRLLS - UN, 2018). Currently there are thirty-seven small island developing States (SIDS) belonging to the United Nations and twenty non-UN members or associate members of regional commissions according to the UN Sustainable Development Knowledge Platform (Appendix A).

*Small size*
Limited natural resource base, high competition between land use, intensity of land-use, immediacy of interdependence in human-environment systems, spatial concentration of productive assets
*Insularity and remoteness*
High external transport costs, time delays and high costs in accessing external goods, delays and reduced quality in information flows, geopolitically weakened
*Environmental factors*
Small exposed interiors, large coastal zones
*Disaster mitigation capability*
Limited hazard forecasting ability, complacency, little insurance cover
*Demographic factors*
Limited human resource base, small population, rapid population changes, single urban centre, population concentrated on coastal zone, dis-economies of scale leading to high per capita costs for infrastructure and services
*Economic factors*
Small economies, dependence on external finance, small internal market, dependence on natural resources, highly specialisation production

[a] *Source*: Lockhart et al. (1993), Conway (1998), Slade (1999).

Figure 1. Vulnerability of small island developing States. Reprinted from Pelling & Uitto (2001, p.53, Box 1).

The exceptional case of small island developing States is recognized by the United Nations through other formal channels. The UN General Assembly created the United Nations Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and the small island developing States (UN-OHRLLS) in 2001 (OHRLLS - UN, 2018). The Alliance of Small Island States (AOSIS) includes forty-four small islands and low elevation coastal countries which represent the small island developing States "as an ad hoc lobby and negotiating voice within the United Nations system" (AOSIS, 2018). The membership of AOSIS consists of 39 States which are members of the United Nations or 20 percent of the United Nation's membership. Nearly 28 percent of small island developing States are developing countries (AOSIS, 2018). According to AOSIS, "Together, SIDS communities constitute some five percent of the global population."

Small island developing States vary in their spatial configuration, from a single island to "highly fragmented multiple islands" (Nurse et al., 2014). There are 115 islands comprising the Seychelles and the Solomon Islands contains 1,000 islands (Everest-Phillips, 2014). The small size of the country and typically large distance to neighboring countries create challenges and specific vulnerabilities for small island developing States (Pelling & Uitto, 2001; see Figure 1). As noted by the United Nations, "Probabilistic models show that small island developing States are expected to bear disproportionately large economic losses attributed to disasters" (DESA - UN, 2018a). Small island developing States are particularly vulnerable to natural disasters, climate change and extreme weather which can be compounded by their possible economic vulnerability and/or lack of coping capacity (World Bank, 2017).

### 2.1.2. Attribute incompleteness

In 2015 the United Nations member states established a set of 17 Sustainable Development Goals (SDGs) to reach by 2030, which interweave social, economic and environmental components of sustainable development (ICSU/ISSC, 2015). Each Sustainable Development Goal is comprised of targets and each target has been assigned one or more indicators for measurement of status towards reaching the target. In total there are 169 targets and 232 indicators.

Table 2. List of nations omitted from SDG Index and Dashboards due to insufficient data. Nations of focus in this study are highlighted.

| Country | Missing Indicators (%) |
|---|---|
| Andorra | 52 |
| Antigua and Barbuda | 39 |
| Bahamas, The | 29 |
| Brunei Darussalam | 28 |
| Cabo Verde | 22 |
| Comoros | 32 |
| Dominica | 52 |
| Equatorial Guinea | 27 |
| Eritrea | 22 |
| Fiji | 23 |
| Grenada | 44 |
| Guinea-Bissau | 23 |
| Kiribati | 44 |
| Korea, Dem. People's Rep. | 34 |
| Libya | 22 |
| Liechtenstein | 73 |
| Maldives | 22 |
| Marshall Islands | 51 |

| Country | Missing Indicators (%) |
|---|---|
| Micronesia, Fed. Sts. | 45 |
| Monaco | 62 |
| Nauru | 65 |
| Palau | 59 |
| Papua New Guinea | 22 |
| Samoa | 34 |
| San Marino | 71 |
| Sao Tome and Principe | 24 |
| Seychelles | 35 |
| Solomon Islands | 30 |
| Somalia | 26 |
| South Sudan | 32 |
| St. Kitts and Nevis | 56 |
| St. Lucia | 34 |
| St. Vincent and the Grenadines | 44 |
| Tonga | 35 |
| Tuvalu | 59 |
| Vanuatu | 27 |

Derived from 2017 SDG Annex & Dashboards (Sachs, Schmidt-Traub, Kroll, Durand-Delacre, & Teksoz, 2017, p.55, Table 2.3).

The Sustainable Development Goal indicators are incomplete. The United Nations seeks more complete datasets through a three-tier classification system based on global implementation of indicator methodology and data availability (IAEG-SDGs - UN, 2017). As noted in the *Review of Targets for the Sustainable Development Goals: The Science Perspective*, "The expanded set of SDGs and targets cover a wide range of topics for which current, detailed, and trustworthy data may not yet exist and for which traditional data collection and integration methods may be technically difficult – or very expensive – to implement" (ICSU/ISSC, 2015). Researchers advocate for the visibility of gaps in Sustainable Development Goal data (Sachs, Schmidt-Traub, Kroll, Durand-Delacre, & Teksoz, 2016).

In analysis for the Sustainable Development Goal Index and Dashboards, 36 countries were omitted due to missing data in 83 indicators, including 25 small island developing States (Table 2). The lack of data for small island developing States is a common problem, not limited to the Sustainable Development Goals. As explained by researchers, "Much of the work in the Caribbean, Pacific and Indian Oceans, and Mediterranean islands is focused at the regional scale rather than being country specific. Because most socioeconomic decision are taken at the local level, there is a need for a more extensive database of simulations of future small island climates and socioeconomic conditions at smaller spatial scales" (Nurse et al., 2014).

## 2.2. Uncertainty visualization

### 2.2.1. Uncertainty visualization cube

The Uncertainty Visualization cube conceptualizes geovisualization of uncertainty among three approaches: static or dynamic, coincident or adjacent and extrinsic or intrinsic (Kinkeldey, MacEachren, & Schiewe, 2014; see Figure 2). Differing from static approaches, dynamic maps include animated, interactive and auditory solutions.

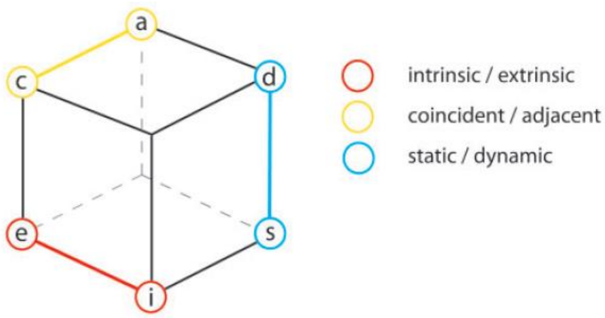



Figure 2. Uncertainty Visualization cube. Reprinted from Kinkeldey, MacEachren, & Schiewe (2014, p. 373, Figure 1).

Coincident approaches display the data and uncertainty within the same map, while adjacent solutions use one map to express data and another to display certainty of data. Most research has been conducted on coincident approaches. Proposed solutions must balance the amount of information displayed in one visualization in coincident approaches with the effort for the user to combine simplified information provided in adjacent maps.

Extrinsic and intrinsic approaches use visual variables. Visual variables were defined by Jacques Bertin as visual cues expressing variations automatically discernible to humans (Bertin, 1981, 1983). The seven visual variables noted by Bertin are: location (X and Y), size, value (of color), texture (or grain), color (or hue), orientation and shape. Cartographers have noted saturation, arrangement, fuzziness and transparency as other visual variables (MacEachren et al., 2012; Morrison, 1974; see Figure 3).

Visual variables can be applied intrinsically or extrinsically to express uncertainty in maps (Kinkeldey et al., 2014). An intrinsic treatment is when visual variables are modified within a map's geometry to represent uncertainty. Most studies analysed by Kinkeldey et al. used intrinsic solutions.

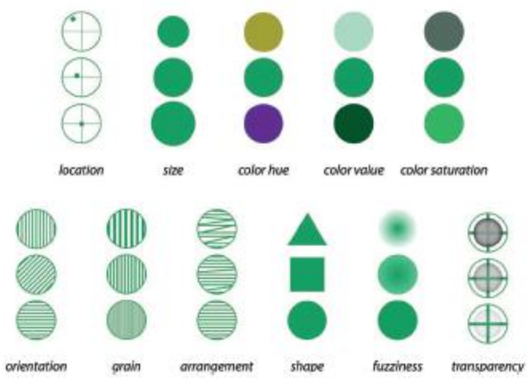



Figure 3. Point symbol differentiation using visual variables. Reprinted from MacEachren et al. (2012, Figure 1).

Alternatively, the extrinsic technique applies graphic symbols to a map, using visual variables to indicate the degree of certainty on the symbol (Kinkeldey et al., 2014; MacEachren et al., 2012; Scholz & Lu, 2014; see Figure 3). Circular point symbols have been studied in extrinsically visualizing uncertainty in maps, in possible combinations with other shapes and contrasting with iconic symbols (MacEachren et al., 2012). Circles are a "more compact" symbol when compared to squares or triangles and offer a "smooth visual impression" (Krygier & Wood, 2005, p.215). In the representation of small nations in maps, *Necklace Maps* were proposed, which used circles of varying sizes and hues placed on the map in ring formats to augment the perceptibility of small nations (Speckmann & Verbeek, 2010).

The representation of small nations using circles (or points) placed in the center of the enumerated unit, or *conceptual points*, can heighten the *visibility acuity,* or angular measurement of the size perceptible to the human eye, which can be translated to a 1.0 mm black dot on a white background at 46 cm distance (Dent, 1993; Slocum et al., 2009). As Buttenfield notes, "Graphical depiction of data quality relies on the strength of human visual acuity for interpreting spatial patterns" (Buttenfield, 1993). According to Bertin, referencing proportional symbols in maps, black points "can be very small indeed if the based map has a light value" (Bertin, 1983, p.362). Though, shapes must be at least 2 mm for its shape to be comprehended (Bertin, 1983).

### 2.2.2. **Visualizing missing data**

The completeness aspect of uncertainty is "to describe the relationship between the objects represented and the abstract universe of all such objects" (MacEachren et al., 2005). The most prevalent cause of incompleteness, or missing data, is that it was not collected (Eaton, Plaisant, & Drizd, 2005). Eaton and colleagues suggest that missing data in choropleth maps have a "perceivable impact" because "users will be expecting to see a value there". However, if users are not expecting to see a value in a small-scale map, the user might not miss the data for small island developing States in a world map. This suggests that imperceptible small island developing States in choropleth world maps results in an "invisible impact," a second level impact according to Eaton et al., where the missingness of the data goes unrealized to users, though in this instance it is due to the size of the States, rather than attribute values, as in other information visualizations.

Robinson explores ways to visualize missing data, either because the data is unavailable (missingness) or the measured data is available yet indicates absence, such as a vacant lot (Robinson, 2018). He argues in certain circumstances there is value in showing what is not available, such as identifying areas that would normally have Twitter users yet during a disaster have no tweets.

Research on the visualization of missing data is limited in cartography. Other disciplines have proposed colored or highlighting techniques, similar to other data categories (Robinson, 2011, 2018). For information visualizations, Eaton et al. suggest three solutions to show missing data: dedicated visual attributes, annotation and animation. According to Eaton and colleagues, dedicated visual attributes apply a "color, texture, shape, or any combination of these." Annotation includes text or graphics next to the visualization. Animation provides more than one perspective on the available and unavailable data within a short time span. It is suggested these solutions could be used together.

An open research question in cartography is whether missing data should be treated as other categories of data or if it requires a different treatment (Kinkeldey et al., 2014; Robinson, 2011, 2018). In addition to applying visual variables to highlight data, Robinson suggests the use of leader lines, style reduction and contouring (2011). Robinson proposes examples of both ways to intrinsically visualize unavailable data in simple, large-scale choropleth maps by using a light gray value or white (blank or without a fill) or changing the hue, value or transparency, in addition to applying blur, texture or shadow treatments to represent missing data. These prototype maps are, by his admission, visually simple, as he foresees complexity with more visually dense maps. Robinson suggests that it is more effective to work with visual metaphors to communicate absence of data and indicates future work is evaluating these methods.

### 2.2.3. Small-scale maps

As in Robinson's missing data prototypes, most cartographic research in visualizing uncertainty has been conducted on large-scale maps. An exception is a study of intrinsic solutions to represent certainty of data using bivariate choropleth world maps (Retchless & Brewer, 2016). Coincident approaches were tested through color and pattern as were adjacent solutions. However, these maps were of certainty relative to global temperature changes, and therefore representing continuous data. Similarly, in *Communicating Thematic Data Quality with Web Map Services,* uncertainty visualizations of continuous data was tested on small-scale maps (Blower et al., 2015).

## 2.3. Research scope

Small-scale choropleth maps are often used to visualize global thematic data, including status towards reaching the Sustainable Development Goals; however, to date, there has not be a review of visualizations or recommendations of ways to represent small island developing States in small-scale choropleth world maps in relation to uncertainty or missing data. The study offers alternative choropleth, small-scale map designs to convey the available and unavailable data values of small island developing States, with a focus on ways traditionally imperceptible nations might be made perceptible to communicate the completeness of a small-scale choropleth map.

There are a few limitations to the study worth noting. This project did not visualize the rate of progress towards reaching Sustainable Development Goals. As the tier classifications indicate, Sustainable Development Goal data is collected at different times and rates (IAEG-SDGs - UN, 2017). Furthermore, effects of newly implemented national policies could appear at varying rates, and more sustainable initiatives might take longer to appear than rapid solutions, making it difficult to evaluate the progress over time (ICSU, 2017). It did not take into consideration the interrelatedness of indicators or the effect of one indicator in relation to others (Sachs et al., 2016). This project did not use time-series visualizations due to insufficient country indicators available over time and therefore did not explore visualizations of uncertainty over time (Sachs et al., 2016). Instead, it focused on the most recent year available.

While cartograms and proportional symbol would offer other visualization solutions of thematic data, these were not examined in this study. The goal of the alternative designs was to maintain the size and identifiable geographic location of countries with an exception for augmenting the perceptibility of small island developing States. This study assumed the geographic identification of small island developing States would be a complex reading task for most users and testing proportional symbols with size variations needing to overlap in small regions or cartograms changing sizes and shapes of nations would overwhelm an introductory study of small island developing State representation. Therefore, this study proposes and evaluates visualization of small island developing States in choropleth world maps.

# 3. VISUALIZATION AND EVALUATION

## 3.1. Overview

To evaluate the visualization of small island developing States in small-scale, choropleth maps and the uncertainty of the Sustainable Development Goal data, this study progressed in three stages. First, small island developing States (SIDS) were defined and classified in a table. During this phase, examples of maps representing small island developing States and uncertainty visualizations were organized in inventories, and static and dynamic cartographic solutions were considered and compared. In addition, Sustainable Development Goal indicators were evaluated based on the completeness of the dataset. In the second phase, maps were created using the selected Sustainable Development Goal indicator. The collection of proposed maps was narrowed, and remaining designs were refined, in the third phase of evaluation, which was initiated through two focus groups, followed by an interview and concluded with an online survey.

## 3.2. Defining small island developing States

A table of small island developing States (SIDS) was initially developed from the SIDS listed on the UN Sustainable Development Knowledge Platform (Appendix A). Per the platform, membership status was noted in the table, either as a full UN member (37 states) or alternatively, a non-UN Member or Associate member of regional commissions (20 states). Full members are grouped by the Atlantic, Indian Ocean, Mediterranean and South China Sea (AIMS), Caribbean and Pacific. Most nations are small islands, though some are coastal countries facing similar social, economic and environmental challenges (OHRLLS - UN, 2018). These nations are Belize, Guyana, Suriname and Guinea-Bissau.

The Global Partnership for Effective Development Co-operation (GPEDC) was listed in association with but not within the count of the 57 SIDS. It was omitted from the SIDS table, keeping in line with a total of 57 states. Sustainable Development Goal indicators also identify small island developing States within each dataset. However, some states included in the small island developing States table were not identified as small island developing States within the indicators. These were five non-UN Members or Associate members of regional commissions: Bermuda, Cayman Islands, Guadeloupe, Martinique, and Turks and Caicos Islands.

A statistician in the UN Statistics Division confirmed there is not a "formal process" to establish the group of small island developing States and suggested to reference the *Standard country or area codes for statistical use* as these "follow the same definition for these groups that was set in 2016 at the start of the SDG period" (I. Rutherford, personal communication, 31 May 2018; UNSD, 2018b). This list was cross-referenced with the SIDS table, which validated the omission of Bermuda, Cayman Islands, Guadeloupe, Martinique, and Turks and Caicos Islands. Bonaire, Sint Eustatius and Saba were included in the *Standard*; however, as of 10 October 2010, these islands are municipalities of the Netherlands (Government of the Netherlands, 2018). These islands are designated in the Natural Earth shapefiles as the Netherlands. Bonaire, Sint Eustatius and Saba were not included in the table, and 52 small island developing States were visualized (Appendix B).

## 3.3. Map inventories

### 3.3.1. Inventory of small island developing States maps

Static and dynamic solutions for visualizing small island developing States were included in an inventory. These drew from Sustainable Development Goal maps created by international organizations to small-scale map research, though could have been expanded to small-scale maps in schoolbooks, atlases and other resources (Appendix C). The Global Assessment Report on Disaster Risk Reduction Atlas lists small island developing States to the side of the map with requisite attribute values (UNISDR, 2017).
In a map developed by the World Health Organization, small islands were represented by point values in varying hues to indicate nominal data. Most small-scale maps centered on the Prime Meridian.

### 3.3.2. Inventory of uncertainty visualization maps

An inventory of uncertainty visualization maps included maps that visualized missingness as well as maps of international institutions that visualized unavailable data and Sustainable Development Goals (Appendix D). It could have been broadened to small-scale maps in schoolbooks, atlases and other resources. The World Bank created a Sustainable Development Goal Atlas using UN indicator data or related World Bank data to visualize the status towards reaching the goals (World Bank, 2017). Our World in Data developed the SDG Tracker to provide related data visualizations such as time-series choropleth maps (Our World in Data, 2018). When data is not available, both organizations apply a light gray value on choropleth maps. In these examples, small countries and their attribute values are sometimes noted with an inset map. The World Health Organization uses two gray values to indicate data that is unavailable and data that is not applicable.

### 3.3.3. Analysis of static and dynamic maps

Choropleth world maps are used to visualize global data such as Sustainable Development Goal indicators; yet, there is a gap in evaluating static and dynamic representations of small island developing States and missingness of data in small-scale maps. Research is mixed on the value of static or dynamic of uncertainty visualizations, which depends on users and tasks. According to Kinkeldey et al. (2017), most uncertainty visualizations created to help in decision-making have been tested in specific domains, such as health research or land-use planning or air defence, making it difficult to apply results to other domains. Though, according to Gerharz and Pebesma (2009): "Generally, it is assumed that static methods are easier comprehensible especially for non-experts, whereas interactive methods offer the control over the amount of information shown which can be useful for understanding the structure of the data."

From a design perspective, compared to interactive maps, static maps provide more control over the composition of the map, including the projections. However, static design solutions do not make use of all the available technology. And the effectiveness of finding countries may be influenced by user's geographic knowledge in static maps. Alternatively, the ability to search for a country name in an open field or select the country name in a list or select a small island developing State region to zoom to view would make it easier to locate areas of interest. Interactive solutions such as a magnifying glass would make small island developing States more visible without modifying the world map. Additional information could be included using a tool tip, when a cursor hovers over a country, which simplifies the design and permits interactivity to learn more information, following the Visual Information Seeking Mantra: "Overview first, zoom and filter, then details on demand" (Shneiderman, 2003).

In a review of uncertainty visualization approaches in user evaluations, Kinkeldey and colleagues found more studies on static maps rather than dynamic, though some dynamic solutions have been offered to simplify an otherwise potentially complex display of information (Kinkeldey et al., 2014). Static maps were selected by this study as an introductory examination of ways to visualize small island developing States which could provide a basis for dynamic approaches in future research. Exploring static maps design solutions is a first step in the research process, such non-interactive solutions proposed for symbolization and design (MacEachren et al., 2012; Robinson, 2011).

### 3.4. Nature of Sustainable Development Goal indicators

The Sustainable Development Goal indicator sought for the visualization would be based on percentage of (sub)population data. There are 232 Sustainable Development Goal indicators classified by the Inter-agency and Expert Group on SDG Indicators into three tiers (IAEG-SDGs - UN, 2017):

- **Tier I:** Indicator is conceptually clear, has an internationally established methodology and standards are available, and data are regularly produced by countries for at least 50 percent of countries and of the population in every region where the indicator is relevant.
- **Tier II:** Indicator is conceptually clear, has an internationally established methodology and standards are available, but data are not regularly produced by countries.
- **Tier III:** No internationally established methodology or standards are yet available for the indicator, but methodology/standards are being (or will be) developed or tested.

As of 11 May 2018, there are 93 Tier I indicators (40 percent) and 72 Tier II indicators (31 percent). Sixty-two Tier III indicators (27 percent) are not available for use. Five indicators (two percent) are a combination of the Tiers due to multiple indicators or indices comprising one SDG indicator. Indicators categorized as Tier I or II were explored for this project.

Using the Tier Classification for Global SDG Indicators list provided in Excel, Tier I and Tier II indicators were isolated for review (IAEG-SDGs - UN, 2018). Most Sustainable Development Goal indicators are based on the percentage of (sub)population data type (Kraak, Ricker, & Engelhardt, Under review). The (sub)population data type would not only be applicable to more SDG datasets, but the visualization of this data type using a choropleth map would be suitable to accommodate visual variables expressing missing data. Therefore, Tier I and Tier II indicators using percentage of (sub)population were analyzed. Indicators were downloaded from the SDG Indicators Global Database maintained by the Statistics Division within the UN Department of Economic and Social Affairs (UNSD, 2018c). Metadata was reviewed to confirm the data type and formulation of the indicator (UNSD, 2018d).

Targets and related indicators which directly reference small island developing States were also considered. For example, Indicator 3.c.1 *Health worker density and distribution* helps to evaluate progress towards reaching Target 3.c *Substantially increase health financing and the recruitment, development, training and retention of the health workforce in developing countries, especially in least developed countries and small island developing States*. Indicators which are used more than once and relate to small island developing States also were considered, such as Indicators 1.5.3/11.b.1/13.1.2, which used *Number of countries that adopt and implement national disaster risk reduction strategies in line with the Sendai Framework for Disaster Risk Reduction 2015–2030*, though this was eliminated because it was binary. Indicator 1.5.4/11.b.2/13.1.3: *Proportion of local governments that adopt and implement local disaster risk reduction strategies in line with national disaster risk reduction strategies* was also considered; however, some Tier II indicators such as 1.5.4 were not available as of May 2018.

There was a wide range of time availability in the indicators; some provided two years of data while others provided more than ten years. The most recent year available varied as well. The span of available years was considered with a focus on finding an indicator with recent available data, defined as within the past three years. Some indicators provided totals as well as disaggregated options such as gender and age. Aggregated and disaggregated data was reviewed to determine: (1) the number of countries with data available (2) the number of countries included without a value (3) the number of countries that were missing from the dataset. For each indicator selected, the completeness of dataset for most recent years was noted in a table. If the indicator had more than 100 countries available for a recent year, the number of small island developing States with data were also included (Appendix E). For data that had less than 100 countries available, the indicators were downloaded from the Open SDG Data Hub (UNSD, 2018b), which provided attribute data for most recent year available. It was suggested that the visualizations might include these less recent indicator values for completeness with the potential to visualize another contribution to uncertainty, recency of data (R. Roth, personal communication, 14 May 2018). This would permit a more complete dataset for consideration, though ultimately it was decided that the dataset should be for one, most recent year before visualizing another aspect of uncertainty.

### 3.4.1. Description of Sustainable Development Goal indicator selected

Accessing data for small island developing States was a challenge in most of the Sustainable Development indicators. The indicator selected to visualize was Indicator 1.1.1 *Proportion of population below the international poverty line, by sex, age, employment status and geographical location (urban/rural).* It is a Tier I data set with 2016 data available for 138 countries and 21 of the 52 small island developing States. The data availability of Indicator 1.1.1 not only permitted testing visualizations of small island developing States but contained a distribution of States with and without data across geographic regions.

Sustainable Development Goal files contain multiple subcategories of data. The subcategory which offered the most available data was used in the creation of the proposed maps. The file was cleaned using a Python script to output the subcategory values of Age group: *15 years old and over* and Sex: *Both sexes or no breakdown by sex* in a csv file. The output of the script summarized the completeness of the dataset, including number of countries with unavailable data for the year and number of countries that had the value of “0” (Appendix F). It would be possible to identify data availability of small island developing States or percentage of their regional availability in this script as well.

## 3.5. Proposed maps

### 3.5.1. Design considerations

The projection, central meridian, and geographic distribution and representation of small island developing States were considered for each map’s composition. At this point, solutions that did not show the regional geographies of small island developing States data, such as a table of islands and values next to the map, were not eliminated to maintain the geographic distribution of small island developing States.

Maps visualizing small island developing States were created using three projections: Winkel-Tripel, Interrupted Goode Homolosine and Mercator. Winkel-Tripel is a compromise projection that minimizes distortion in angle, area and distance. It is similar to the Robinson projection, also a compromise projection, though has less areal distortion at the poles (Krygier & Wood, 2005). The Winkel-Tripel replaced Robinson as the standard projection used by National Geographic Society in 1998. The Interrupted Goode Homolosine projection is an equal area, composite projection developed by Goode in 1925, who introduced *map projection fusion* by combining Sanson’s sinusoidal projection in the low latitudes and the Mollweide projection in the high latitudes (Canters, 2002). As Canters notes, “the equal-area property has for a long time been considered as the most important property for world maps, especially for the mapping of statistical data” (p.57). Mercator, a cylindrical conformal projection, preserves angles but has dramatic distortion at the poles. It was included due to its familiarity for users and continued prevalence in world maps, despite the recommendation to stop using the Mercator projection in the Resolution Regarding the Use of Rectangular World Maps in 1989 signed by American Cartographic Association, American Geographical Society, Association of American Geographers, Canadian Cartographic Association and the National Geographic Society, among others (Dent, 1993).

Static maps were designed for a typical size used in print publications of a landscape A3 paper, 42.0 x 29.7 cm, equivalent of an A4 spread. The location and design of the legend was kept consistent. While attribute values of "0" had been reviewed as the absence of poverty, the focus of this study was on visualizing missing data. As a result, "0" was included in the first class, rather than a separate class. The data skewed right; therefore, the Jenks natural breaks classification was used as a basis to establish the start of each class with a number divisible by 10 after the lowest class of 0-9%. The hue was selected to match the red color scheme of Goal 1 and represent the urgency of the map's theme to show proportion of population living below the international poverty line. Five classes were used to represent the dataset, though six or seven values of red can be discerned (Kraak & Ormeling, 2003). The colors were derived from ColorBrewer in a single-hue color scheme (colorbrewer2.org). A gray value represented no data.

Natural Earth shapefiles were used to create the maps. Tuvalu was so small, it was not included in the standard Natural Earth 1:110m or 1:50m shapefiles and was added from a Natural Earth *Tiny Country Points* file. Using ArcMap, the location of each small island developing State was determined by the centroid of the country and a circular point symbol was extrinsically applied to identify locations of small island developing States (MacEachren et al., 2012). The attribute value of the State was represented by the color fill. The file was then exported to Illustrator and countries that were covered by the point due to size were removed from the map, including multi-island nations. Countries that were large enough to appear around the applied point were maintained. Disputed borders or territories were not considered for this map due to the focus on small island developing States; however, disclaimer language was included.

Five maps were proposed at the start of the study, referred to as Maps A-E (Table 3; see Appendix G for larger images). Maps A-C used the Winkel-Tripel projection and points to represent the small island developing States. Points in the Caribbean were significantly overlapping. In Map A, a circle provided a guideline to place the leader lines and points (Figure 4).

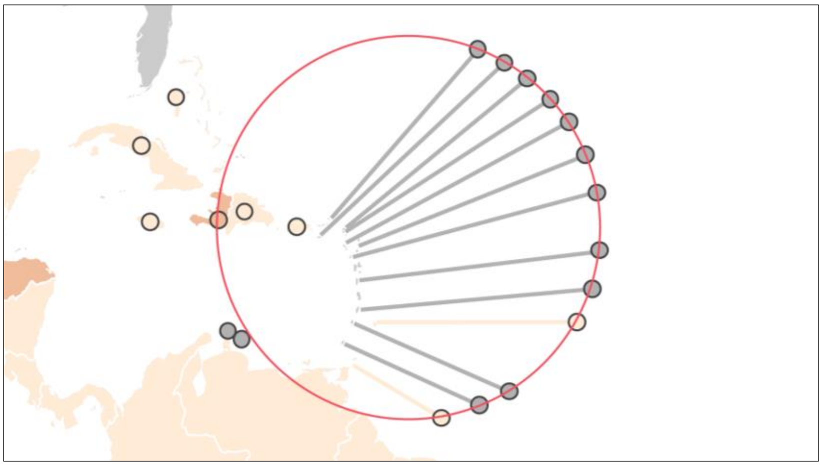
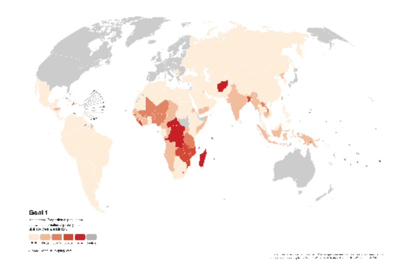
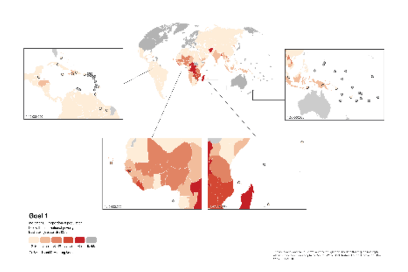
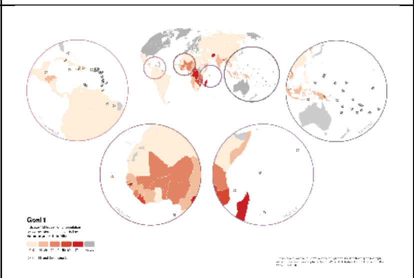
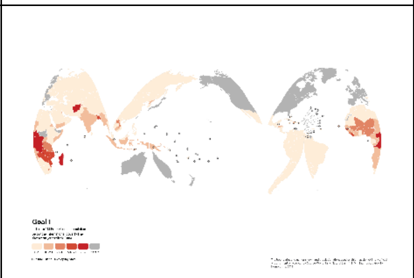
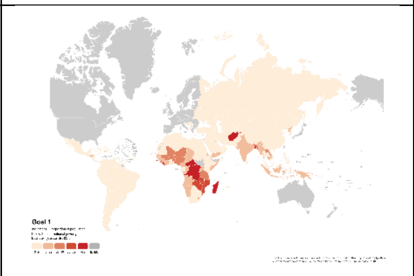


Figure 4. Circle used to place small island developing State points in Caribbean.

Map B and C tested changes in scale to improve the perceptibility of these States. Map B used rectangular inset maps in four small island developing State regions and Map C used a magnifying lens design in a zoomed display of the regions. In this regard, Map B was inspired by the dynamic solution of zooming to a select regional view and Map C interpreted a dynamic solution of using a lens to magnify a region. Both used the Winkel-Tripel projection. Each circle of the inset or lens set the central meridian to the area of

Table 3. Five proposed maps.

| | Map | Projection | Central meridian | SIDS representation |
|---|---|---|---|---|
| A |  | Winkel-Tripel | 48°E | Points for SIDS; leader lines for Caribbean |
| B |  | Winkel-Tripel | 48°E Each inset map centered on each region | Inset maps of SIDS regions; points for SIDS |
| C |  | Winkel-Tripel | 48°E Each inset map centered on each region | Magnifying lens on SIDS regions; points for SIDS |
| D |  | Interrupted Goode Homolosine | 160°W | Points for SIDS; leader lines for Caribbean |
| E |  | Mercator | 48°E | ISO-alpha3 codes for SIDS; leader lines for Caribbean |

focus. Map C used four magnifying lenses to focus on each of the small island developing State regions. It was challenging to set a map scale and lens size that would be consistent for all four lenses. Ultimately the lens focused in the Pacific Ocean used a smaller scale than the other three lenses and each lens was labeled with a scale. Drafts for the map using magnifying lenses included leader lines from the lenses pointing to the center of the magnified area (Figure 5), two lines representing cones of focus to the magnified area and multiple colored outlines for lenses. The solution with leader lines and cones to the lenses were omitted because the lines started to create a graphical object detracting focus from the map. Black outlines without leader lines to the area of focus did not create a strong relationship while saturated lines created detracted from the color values of the map. Strokes of the focus area and related lens were subtly linked with four desaturated colors.

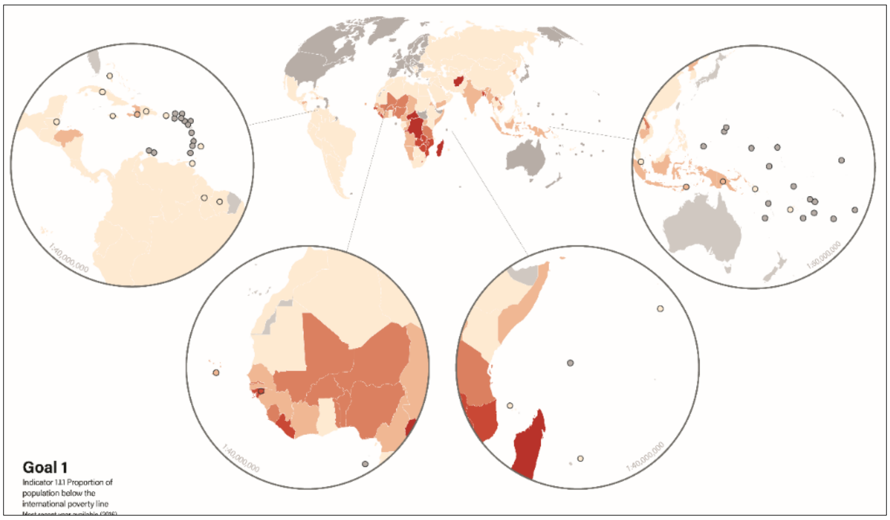



Figure 5. Draft of magnifying lens visualization using leader lines to identify each magnified region (cropped here in Winkel-Tripel projection).

Map D was created using the Interrupted Goode Homolosine projection, which was centered in the Pacific and represented small island developing States with point symbols. Similar to Map A, Caribbean islands in Map D identified with leader lines. was based on two curves. A single circle was tested in Map A while Map D used two circles as guidelines. Small island developing States in the Caribbean were available in Natural Earth's 1:50m shapefile but not the 1:110m file. Map D used a 1:110m shapefile with a second layer of 1:50m shapefile to identify the Caribbean islands (Figure 6). The two circles were used to follow the interior and exterior locations of the islands. The circle and islands were then removed.

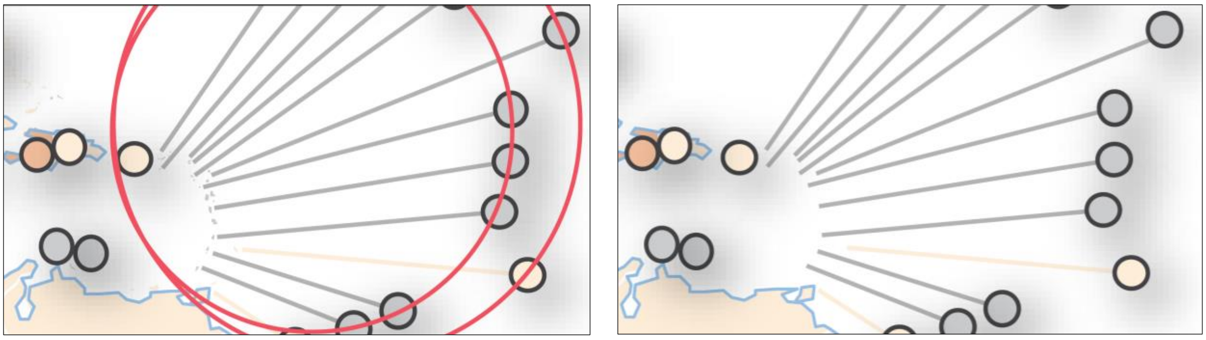


Figure 6. Two circles used for placement of States and 1:50m layer to identify Caribbean locations.

Map E was created with the more familiar Mercator projection and tested the use of ISO-alpha3 codes. ISO-alpha3 codes are unique, three-letter codes to identify each country, which are maintained by the International Organization for Standardization. The ISO-alpha3 code was placed on the centroid location unless the State was large enough to be labelled or in the case of the Caribbean, leader lines identified the location of the small island developing State.

### 3.6. Evaluation of maps

Two focus groups and an interview helped to evaluate and narrow the selection of five visualizations before testing via an online survey (Table 4). Focus groups identified preferences in maps and informed revisions to the designs. As noted by researchers, "Focus groups are excellent ways to probe users' attitudes, beliefs, and desires. They don't, however, give you information about what users would actually do with a product. The data are what people say they think or do or need. A focus group, therefore, is not a technique for verifying or assessing the usability of a product" (Dumas & Redish, 1999, p.45). Therefore, after an interview was conducted, an online survey was developed to gain feedback from a large and diverse set of users, testing for effectiveness and satisfaction (Roth, Ross, & MacEachren, 2015). Few assessments of the communication of uncertainty visualizations use qualitative approaches such as interviews or focus groups; most evaluations use quantitative approaches in lab studies or web-based studies (Kinkeldey et al., 2014).

Table 4. Methods of evaluating maps.

| Method | Number of participants | Date | Number of maps |
|---|---|---|---|
| Focus group 1 | 4 | 5 July 2018 | 5 |
| Focus group 2 | 6 | 12 July 2018 | 2 |
| Interview | 1 | 13 July 2018 | 1 |
| Online Survey | 94 | July to 14 August 2018 | 1 |

#### 3.6.1. Focus group 1

The first focus group drew from participants randomly selected at Geo-Information Processing (GIP) Research meeting consisting of a Ph.D. student and three professors at the ITC Faculty of Geo-Information Science and Earth Observation at the University of Twente. The four participants were introduced to the five maps one-by-one. Once all five maps available to see, participants were asked to respond to each map. Each visualization was discussed using prompting questions related to how well the map shows the distribution of data and how easy it might be to retrieve data values for Caribbean islands. The conversation then moved to the design such as likes or dislikes and whether the projection was appropriate to communicate small island developing States data. Participants provided permission to record the focus group, which lasted 30 minutes. For each map discussed, notes were taken on a copy of the map to capture conversational points on specific areas.

#### 3.6.2. Focus group 2

Based on the feedback from the first focus group, the maps were narrowed to two designs, Map C, the magnifying lens using the Winkel-Tripel projection, and Map D, the Interrupted Goode Homolosine projection. These maps were refined based on user feedback and presented to a focus group of cartography experts consisting of an MSc. Cartography student and ITC professors identified as cartography experts. Permission was provided to record the conversation by video and audio, which lasted 30 minutes. Participants provided feedback on the map from the perspective of cartographers. Similar to Focus group 1, notes were taken on an adjacent copy of the map.

#### 3.6.3. Interview

Following the focus group of cartographers, an interview was conducted with Latoya K. Burnham, a representative working in communications for a multi-national consortium of states in the Caribbean. She responded to the map design selected by the focus group of expert cartographers and provided perspective on challenges in data availability and visualization in the Caribbean.

#### 3.6.4. Online survey

Based on the feedback from the expert cartographers and the interview, Map D, using the Interrupted Goode Homolosine projection, was selected and revised for testing via an online survey. Geographic-related scientists and representatives from international organizations and small island developing States were recruited as participants in the online survey to receive diverse yet specialized perspectives on the map. Snowball sampling was used via personal and professional networks to reach representatives of these specific groups. Individuals were contacted through Twitter, Skype groups and email. Cartographers were written through the International Cartographic Association Commissions on Cognitive Issues in Geographic Information Visualization, Visual Analytics, and Use, Users and Usability issues. Representatives from international organizations such as the World Bank, International Monetary Fund and United Nations were contacted with requests to complete the online survey and send to potentially interested parties. Attempts to reach representatives from small island developing States were made through emails to the Secretariat of the Pacific Regional Environment Programme (SPREP) and Caribbean Community (CARICOM) as well as through other personal contacts in order to receive feedback from those who are from, live or work on small island developing States.

##### 3.6.4.1. Survey questions

At the beginning of the survey, participants were asked to indicate their experience using print and web maps, designing maps and working at an international organization. This captured multiple forms of expertise among participants (Kinkeldey et al., 2014). In addition the survey asked for contextual individual differences, such as experience of small island states, including but not limited to small island developing States (Smith Mason et al., 2017). This was to capture experience with small island states that might not be included in the category of small island developing States for this project.

The evaluation of the maps was focused on effectiveness and satisfaction, two of the three recommended components of usability recommended by the International Organization for Standardization in ISO 9241-11. Efficiency was not evaluated, rather correct responses and satisfaction among users were prioritized in this preliminary study. The online survey provided an objective and subjective assessment of the visualization (Kinkeldey et al., 2017, 2014). Objective assessment included *where* and *what* questions were used to evaluate communication of spatial and attribute certainty (Roth et al., 2015). Participants were asked *identify* and *compare* questions at the *elementary* and *general* search levels (Roth, 2013). After each series of questions, grouped by search levels, respondents rated the level of effort it took to answer these questions using the map on a Likert scale, which provided a subjective assessment of the map through a rating of satisfaction (Kinkeldey et al., 2017). A subjective assessment was also provided in an open comments section after completing the map tasks. Users were encouraged to give feedback on the design, such as the color, projection and symbols.

An exit survey was used to gather demographic information on the participants. This included educational experience of a geographic-related science as another form of checking for expertise. All questions were optional to encourage the completion of the survey. Before the survey was sent, four participants were trial users in varying ages. Changes to the map size and text labelling were maximized and instructions for zooming were provided.

# 4. RESULTS

## 4.1. Focus group 1

In response to Map A, participants in the first focus group found it easy to see missing data but wondered why there was not more data available. They noted the points representing small island developing States were very small and that they had to look closely to "see the color." Some users disliked the leader lines in the Caribbean, describing it as a "flower" or "fan-like" form, which was distracting.

For Map B, participants liked the inset maps. As one user said, "I like the philosophy behind it—to zoom in. It is important to show the small islands." Users wondered if the world map could be reduced in size and then the insets could be increased in size and show the islands at a larger scale. For the Caribbean, users thought displacement could be used to slightly separate some of the points from one another. Missing data was brought up as one user mentioned that the Caribbean is "a bunch of points with no data." They debated the inset of Africa, whether more related context should be kept or cropped to focus on the islands.

Participants noted that when all the maps were introduced, Map C had caught their attention. Three of the four users agreed that they preferred this solution over the first two immediately. One user said, "I like this one a lot" though another thought the "zoom in better with a rectangle," referring to the insets of Map B. It was noted that the design was clear. Again, users found it strange to focus on the islands and yet lack data for so many of them. One participant asked, "Is important to show no data in order to ask for more data?"

In Map D, participants were not comfortable with the projection. One user said, "The projection is distracting because it is not commonly used." Another felt more strongly: "I hate any map that rips up land masses." Another said, "The topology is completely messed up... I need to fix this… I feel like I've fallen on my head." One user countered, "What I like is that the small island developing States that you want to highlight stand out, but this is as if you are not interested in the rest of the world." Another user agreed that "it was an advantage to show the small island developing States." This brought the discussion to question if the other maps could be centered on the Pacific. Participants thought displacement could be utilized in the Caribbean. Commenting on the alternative leader lines, one user said, "It could be an attempt to make it three-dimensional, which is confusing." Then a participant asked, "If this is really about small island developing States why spend so much ink on the continents? Throw them away. Should this be a global map?" A user mentioned, "The thing is – whatever stands out the most becomes the most important… and in all these maps what stands out is central African countries because of the color, size and problem. But these maps are about small island developing States… they will lose against central Africa…." Another user continued, "Yet what is the map about? We have no data?"

Users were more comfortable with the projection in Map E. However, they were not familiar with ISO-alpha3 codes saying, "I don't think this tells the message you want to tell" and "I didn't even get it." In response, one user said, "…too little exposure—but a little more time you would get it." While a user thought it was good to have the name of the countries, it was questioned whether there might be a table with the small island developing States data. Colors were noted as too light and the color scale was suggested to be changed.

#### 4.1.1. Revised design

Maps C and D attracted the most discussion in Focus group 1. Map C had caught the users' attention and offered enlarged views of the islands through a magnifying lens. Map D had elicited the most debate given the projection, yet users thought it offered the most focus on the small island developing States. These two maps were revised before seeking feedback from the second focus group.

In Map C, the size of the magnifying lenses and world map were retained because they were a compromise given the available space on the page, which balanced the size of the lenses, the scales of the magnifying lenses and size of the overview provided by the small map. The lenses could not be enlarged much more and fit on the page. A thin bounding box was added to the small map, and it was lowered on the page closer towards the lenses based on user feedback.

In Map D, points representing the small island developing States were enlarged and a drop shadow was added to each point to emphasize the small islands. The outline of the world, equator and 180th meridian were created in blue, which necessitated the inclusion of Antarctica. Antarctica was not given a color fill, not even for missing data because it is not tracked for this indicator. The title was modified and moved up on the page based on user feedback. Two small overview maps were included, one that centered on Europe and Africa and the other which centered on the Pacific. This was to provide context in response to user feedback that the projection was disorienting.

In both maps, islands that were large enough to surround the point representing the small island developing State were maintained on the map. Island smaller than the entire area of the point, such as fragmented islands around a point, were removed to simplify the visual representation. Without enough context to provide users in responding to the map as decision makers, this role was omitted in the next focus group and online survey. Color was not noted as a problem in Maps C or D. Color perception was expected to be a problem in Map E but was not modified earlier as these were prototypes to create quickly to receive feedback on the concept. In addition to the small point size representing islands, color perception might have also been exacerbated due to the printer and quality of paper.

### 4.2. Focus group 2

Feedback on Map C, using the insets of magnifying lenses, suggested that the design was not immediately easy to interpret (Figure 7). Cartography experts found the composition of the map chaotic and identified a desire for a layout change either by moving the location of the lenses on the page or reducing the size of the world map. This led the conversation to the point that the world map provides overview and the lenses show values for each State but do not show overview. Therefore, more elementary questions would be answered on the insets. Furthermore, it was not immediately apparent that the lenses were linked to the regions that they identified, possibly due to the subtle hue differences of desaturated colors selected. Magnifying lenses should be thinner and the color needs to be considered. It was suggested that lead or projection lines might be used to indicate the region magnified rather than the same color of lens outlines. Experts discussed the difference in scale of the lenses. There was apprehension that three used the same scale and the fourth used a smaller scale. While there was one suggestion to add toponyms in the magnifying lenses, the idea to label the small islands using ISO-alpha3 codes was rejected. It was recommended to use the toponym of the country or omit it. It was questioned if the same data could have been shown using a world map that filled the page rather than the lens solution.

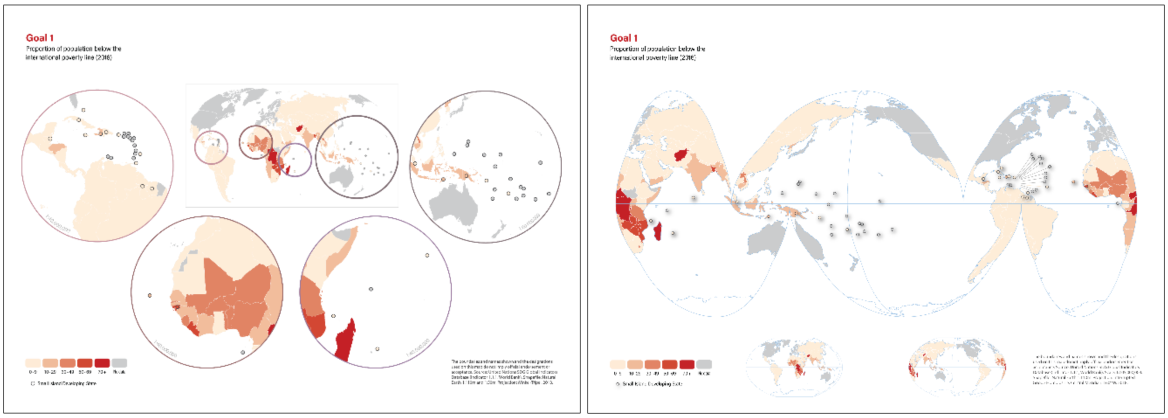



Figure 7. Map C (left) and Map D, which were presented to Focus group 2.

Cartography experts found Map D, using the Interrupted Goode Homolosine projection, more favorable. Participants debated whether non-scientists would understand projection. In conclusion a participant noted, “It challenges world view but shows distribution better.” One user said that the central meridian helped focus the design. Feedback included to remove the small, overview map centered on the Prime Meridian or possibly both maps. A suggestion was made to remove the leader lines and allow the points to overlap in the Caribbean with slight displacement or to change the scale of the Caribbean lobe.

It was mentioned there was not enough differing data values in dataset to test for the full scale of the choropleth map. One suggestion was to find data or test with a dataset that was more complete. It was noted that users may have trouble identifying five color values in the points, referencing Jacques Bertin for the maximum of three distinguishing values of points for selection, or to see patterns of categories of data. Experts suggested that the missing data in the indicator would be frustrating for viewers without more context of the project. Overall the experts wondered why the title did not directly reference small island developing States and whether the maps were to show the small island developing States compared to the rest of the world or only small island developing States. All participants preferred Map D to Map C with one respondent expressing an interest in seeing an uninterrupted projection at the same scale.

#### 4.2.1. Interview

In the interview, Latoya K. Burnham, a communications professional in a multi-national consortium of states in the Caribbean, noted the difficulty accessing recent data for Caribbean islands. She mentioned when Caribbean data is included regionally as *Latin America and the Caribbean,* it appears as if the dataset is more complete due to the greater availability of Latin American data than the Caribbean. In response to the design, Burnham wondered if a magnifying lens might be used in an interactive map to more closely inspect islands. The most salient point provided in the conversation was that “overlapping circles would be offensive” to represent Caribbean countries because this suggests that each country is not important enough to display as a fully visible circle (or point). This comment was kept in mind for the revised design tested in the online survey.

#### 4.2.2. Revised design

Cartographers preferred the Interrupted Goode Homolosine projection for its use of the full page to show the distribution of data. One cartographer wanted to see a sample of an uninterrupted projection, which echoed the preferences of some in first focus group.

The reference to Jacques Bertin’s maximum of three values in points to be distinguishable as groups was notable (Bertin, 1983). According to Bertin, this meant that users would not be able to visually group the geographic distribution of small island developing State indicator values within a region or world-wide if there were more than three classes. The map could still be suitable for identification of island values in five classes. For this dataset there were only three data values available for small island developing States, plus a gray value representing unavailable data. In this regard, it would not represent a comprehensive test for the full five values of this classified map. Furthermore, testing for perceptual selectivity is limited due to the sparseness of data available to selectively see. Given the lack of multiple islands with the same value, the largest group of islands to perceive as one group would be the ones without data, represented with a gray value. Representation of unavailable data was attempted using an inner drop shadow on the point symbols to look as if the point was empty. This was a similar solution to Robinson's proposal of a shadow to represent missing data. Point values were then given an outer drop shadow tightly bound to the outline. These solutions were too nuanced to display in small point size of a vector file.

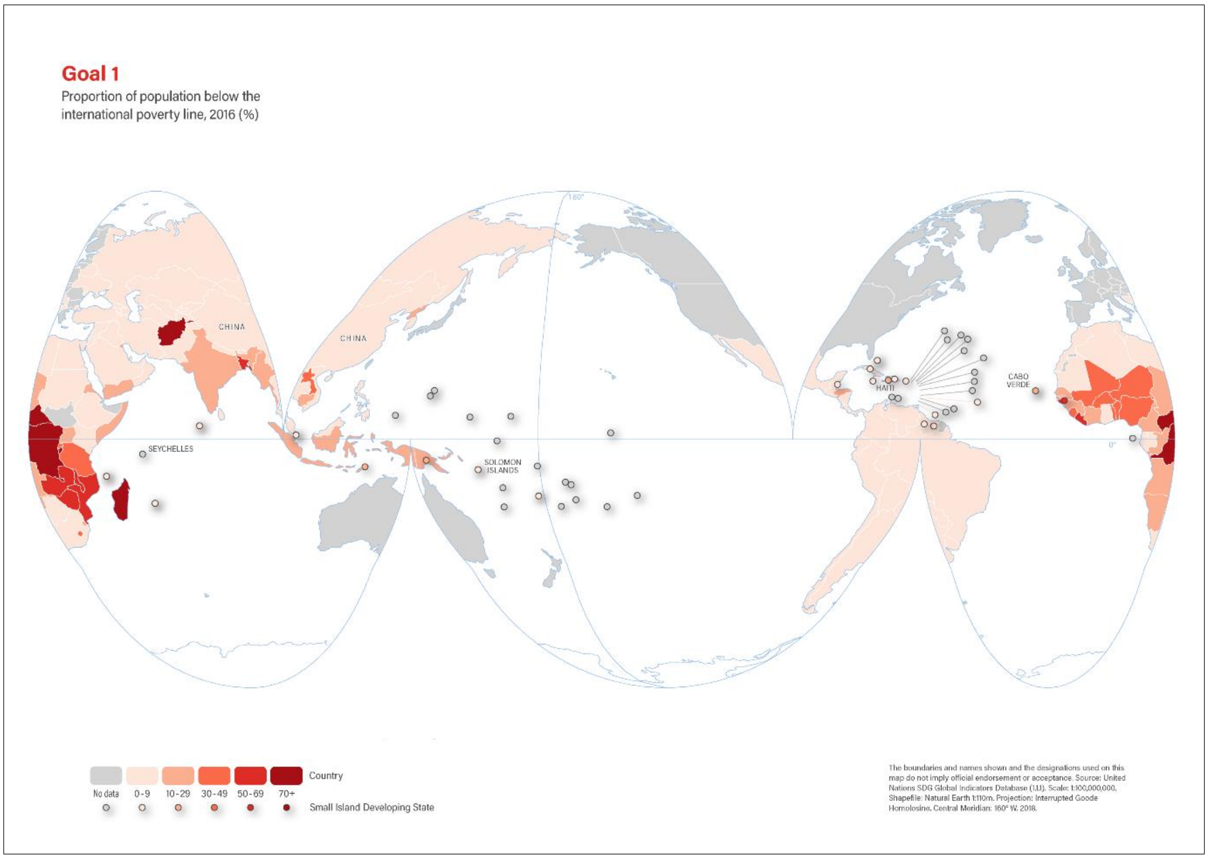



Figure 8. Map D evaluated in online survey.

The scale was increased to 1:100,000,000 to make use of the full page and enlarged the points representing the small island to 2.11 mm to increase perceptibility. Symbolization was added to the legend to represent each potential attribute value of small island developing State. The small reference maps were removed from the bottom of the map. Leader lines were maintained in the Caribbean to display the full point representing each State rather than overlapping might reduce perceptibility.

In preparation for the online survey, the colors were modified using the RGB color build offered in ColorBrewer for the same color ramp rather than the CMYK build that was used for printed maps (Figure 8). Points representing small island developing States in each color value were added to the legend to add clarity for the user. While abbreviated codes to label countries had been of interest, the expert cartographers also cautioned against using ISO-alpha3 codes. The solution was to omit toponyms in the map and label the countries referenced in the online survey. The title was not modified to see what the users believed to be the appropriate purpose of the map.

## 4.3. Online survey

There were 105 participants in the online survey. While users were permitted to skip questions and still complete the survey, eleven of the responses were omitted due to incompleteness. In these instances, respondents filled out introductory information but did not answer questions related to the map nor provide feedback. The resulting 94 responses are used in the following analysis. Identification, comparison and overview questions directly related to the visualization were answered by 78 to 88 respondents (Appendix J). Others provided comments in an open field towards the conclusion of the evaluation.

### 4.3.1. Demographics and experience

Thirty-six percent of respondents were female and 63% were male; 1% preferred not to specify. Respondents were between the ages of 18-24 (2.53%), 25-34 years old (26.58%), 35-44 years old (30.38%), 45-54 years old (19%), 55-64 years old (10.13%) or 65 years or older (10.13%). A small percentage (1.27%) preferred not to specify age. The highest degree in a geographic-related science by respondents was high school (17.72%), some college but no degree (3.80%), BSc (8.86%), MSc (30.38%), PhD (34.18%) or none of the above (5.06%).

Most respondents used a paper or digital map every day (54.84%) or a few times a week (33.33%); others responded about once a week/few times a month (8.61%) or less than once a month (3.23%). Respondents designed maps every day (8.60%), a few times a week (11.83%), about once a week (9.68%), a few times a month (18.28%) or once a month (11.83%). Forty-percent of respondents designed maps less than once a month. Most respondents were somewhat to extremely interested in international politics. Respondents indicated they were extremely interested (25.53%), very interested (46.81%) or somewhat interested (25.53%) in international politics.

In response to the statement that best described the participant's experience with small island states (n=94), 4.26% currently live on a small island state, 7.45% had lived on a small island state for two months or more and 11.70% had worked on a small island state (Figure 9). Nearly 30% of respondents had been to a small island state on vacation. Thirty-four percent of respondents had never been to a small

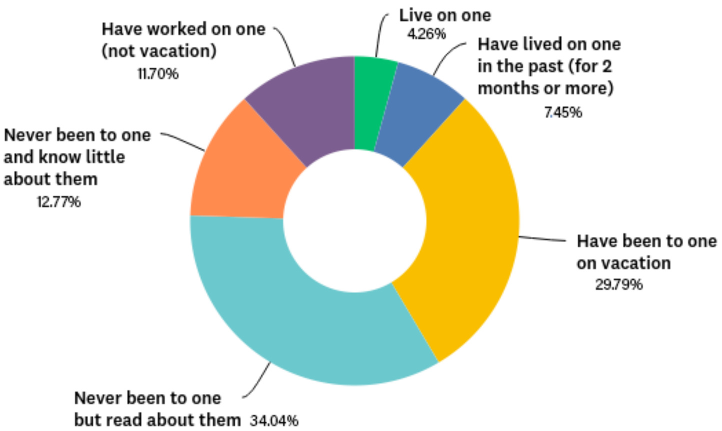



Figure 9. Experience of respondents with small island developing States.

island state but had read about them. Approximately 13% of respondents had never been to a small island state and knew little about them.

Table 5. Nationalities and current country of residence of respondents. Representation from small island developing States are highlighted.

| Nationality | Percentage (%) | Number of Respondents (n=76) |
|---|---|---|
| United States | 23.68 | 18 |
| Germany | 10.53 | 8 |
| Canada | 7.89 | 6 |
| Australia | 5.26 | 4 |
| Finland | 5.26 | 4 |
| Switzerland | 5.26 | 4 |
| United Kingdom | 5.26 | 4 |
| Brazil | 3.95 | 3 |
| Netherlands | 3.95 | 3 |
| Belgium | 2.63 | 2 |
| Seychelles | 2.63 | 2 |
| Spain | 2.63 | 2 |
| Austria | 1.32 | 1 |
| Bolivia | 1.32 | 1 |
| China | 1.32 | 1 |
| Czech Republic | 1.32 | 1 |
| Ireland | 1.32 | 1 |
| Italy | 1.32 | 1 |
| Latvia | 1.32 | 1 |
| New Zealand | 1.32 | 1 |
| Nigeria | 1.32 | 1 |
| Puerto Rico | 1.32 | 1 |
| Russia | 1.32 | 1 |
| Saint Vincent and the Grenadines | 1.32 | 1 |
| Senegal | 1.32 | 1 |
| Slovakia | 1.32 | 1 |
| Slovenia | 1.32 | 1 |
| Tunisia | 1.32 | 1 |

| Current Country of Residence | Percentage (%) | Number of Respondents (n=77) |
|---|---|---|
| United States | 29.87 | 23 |
| Netherlands | 11.69 | 9 |
| Switzerland | 10.39 | 8 |
| Australia | 5.19 | 4 |
| Finland | 5.19 | 4 |
| Germany | 5.19 | 4 |
| Seychelles | 3.90 | 3 |
| United Kingdom | 3.90 | 3 |
| Brazil | 2.60 | 2 |
| Canada | 2.60 | 2 |
| Senegal | 2.60 | 2 |
| Austria | 1.30 | 1 |
| Belgium | 1.30 | 1 |
| Bolivia | 1.30 | 1 |
| Burundi | 1.30 | 1 |
| Czech Republic | 1.30 | 1 |
| France | 1.30 | 1 |
| Italy | 1.30 | 1 |
| New Zealand | 1.30 | 1 |
| Nigeria | 1.30 | 1 |
| Panama | 1.30 | 1 |
| Rwanda | 1.30 | 1 |
| Saudi Arabia | 1.30 | 1 |
| Spain | 1.30 | 1 |

Respondents provided their nationality and current country of residence (Table 5). Nearly a quarter of respondents or 18 people were from the United States; other participants were from Germany (8), Canada (6), Australia (4), Finland (4), Switzerland (4), United Kingdom (4), Brazil (3), and Netherlands (3). Reported nationalities representing small island developing States included two from the Seychelles, one from Puerto Rico and one from Saint Vincent and the Grenadines. Highest number of responses for current country of residence include the United States (23), Netherlands (9), Switzerland (8), Australia (4), Finland (4), Germany (4) and United Kingdom (3). Three people indicated they live in the Seychelles.

Forty respondents had worked at an international organization (Table 6). Of those who indicated the length of time working in an international sector (n=38), 28.95% noted it was less than a year, 36.84% for 1-4 years, 21.05% for 5-9 years and 13.16% for more than ten years. Of those who indicated the sector in an open field (n=36), the most common responses were: 25.00% humanitarian, 22.22% in cartography or geographic-related science, 8.33% in academia or higher education, 8.33% in disaster management and 8.33% in information management.

Table 6. Thirty-six respondents listed the sector of their international work experience. Descriptions may apply to same person due to open response field.

| International sector | Percentage (%) |
|---|---|
| Humanitarian | 25.00 |
| Cartography or Geographic-related Science | 22.22 |
| Academia or Higher Education | 8.33 |
| Disaster Management | 8.33 |
| Information Management | 8.33 |
| Communication | 2.78 |
| Coordination | 2.78 |
| Data Visualization | 2.78 |
| Development | 2.78 |
| Economics | 2.78 |
| Engineering | 2.78 |
| Environment | 2.78 |
| Government | 2.78 |
| NGO | 2.78 |
| Peacebuilding | 2.78 |
| Research | 2.78 |
| Social Science | 2.78 |
| Sustainability | 2.78 |

### 4.3.2. Identification

Eighty percent of responses to identification questions for small island developing States were correct (Figure 10). While 80% of respondents (n=88) were able to identify the poverty rate for Cabo Verde,

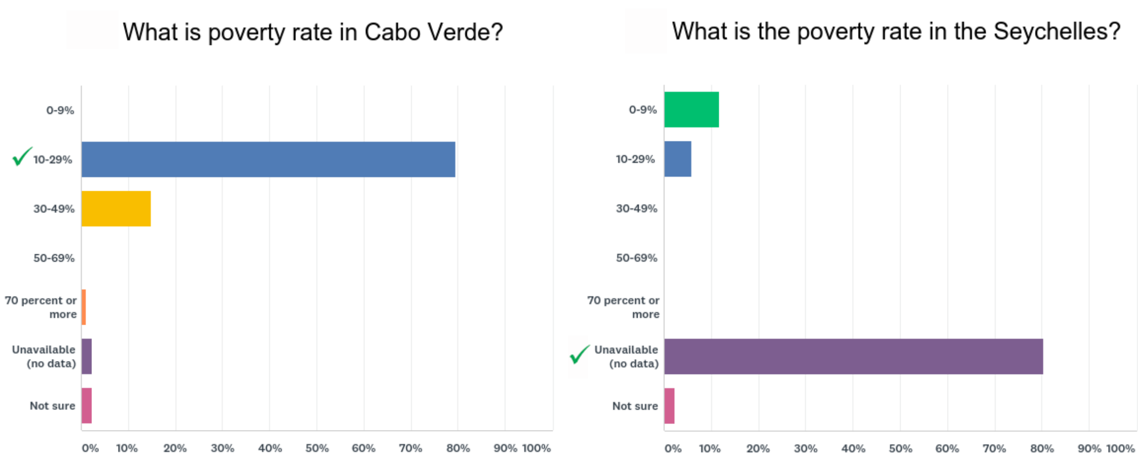



Figure 10. Identification questions for small island developing States received 80% correct responses.

14.77% misidentified the point as belonging to the next class of 30-49%. Most respondents (n=86) correctly identified that the data was unavailable for the Seychelles (80.23%). Other respondents identified 0-9% or 10-29% (11.63% and 5.81% respectively). The poverty rate for China was correctly identified by 86.05% of the participants and 10.47% selected the next higher class. Respondents indicated the map made the elementary identification questions: very easy (14.94%), easy (47.13%), neither easy nor difficult (18.33%), difficult (17.24%) or very difficult (2.30%).

#### 4.3.3. Comparison

Most participants (96.43%) correctly answered that Haiti had a higher rate of poverty than the Solomon Islands. In response to the region of the world that has countries with higher poverty rates than the small island developing States in the Caribbean, most respondents (92.86%) correctly identified Central Africa. Respondents indicated the map made the comparison questions: very easy (12.94%), easy (34.12%), neither easy nor difficult (31.76%), difficult (20.00%) or very difficult (1.18%)

#### 4.3.4. Overview

More than half of the participants (64.56%) estimated correctly that 75% of the small island developing States were without data in the Pacific; however, 17.72% estimated 100% and 8.86% were not sure. In response to the question of the approximate percentage of small island developing States without data world-wide, most respondents (68.35%) incorrectly estimated 75% rather than 50%. Only 12.66% of participants answered correctly. There were 8.86% who were not sure. Half of the participants correctly estimated the percentage of all countries without data world-wide; 10.13% of respondents estimated 75% and 13.92% of respondents were not sure. Participants indicated the map made these questions: very easy (1.25%), easy (21.25%), neither easy nor difficult (36.25%), difficult (28.75%) or very difficult (12.50%).

#### 4.3.5. Design

Most of the participants in the online survey thought that the map design was appropriate to show available and unavailable data for small island developing States with 12.66% strongly agreeing and 54.43% agreeing with this statement. Other responses include: neither agree nor disagree (7.59%), disagree (20.25%) or strongly disagree (5.06%).

- For those with an MSc or PhD in a geographical-related science (n=51) were less neutral: 11.76% strongly agreed, 56.86% agreed, 1.96% neither agreed nor disagreed, and 25.49% disagreed and 3.92% strongly disagreed.

- For those who had worked in international organizations (n=39), which could include those with an MSc (n=12) or PhD (n=9) in a geographical-related science, the responses were the following: 17.95% strongly agreed, 48.72% agree, 10.26% neither agree nor disagree, 17.95% disagree and 5.13% strongly disagree.

- For those who live on a small island state (n=4), 25.00% agreed, 25.00% neither agreed nor disagreed, 25.00% disagreed, and 25.00% strongly disagreed.

- For those who had worked on a small island state (not vacation) (n=8), 25.00% strongly agreed, 25.00% agreed, 37.50% disagreed and 12.50% strongly disagreed.

- For those who had lived on a small island state in the past (2 months or more) (n=6), 16.67% strongly agreed, 50.00% agreed and 33.33% disagreed.

Compared to the response to the appropriateness of the design to show small island developing States, participants were less supportive of the design to show available and unavailable data for all countries (n=78): 5.13% strongly agreed, 39.74% agreed, 17.95% neither agreed nor disagreed, 30.77% disagreed and 6.41% strongly disagreed.

Impressions of the map design were provided by 49 participants in the study. Users were prompted to write in an open field their likes, dislikes or suggestions for improvement. It was suggested that they might consider responding to the colors, symbols and map projection used. These responses were classified as **positive, neutral, negative, adjustment and addition.** A participant's statement could be coded twice to be included in each corresponding category. **Positive, neutral and negative** responses related satisfaction of the design. **Adjustment** responses were suggestions for improvement and **addition** responses were suggestions that were outside of the scope of the project.

**Positive** feedback included comments supportive of the projection (18.37%), design (12.24%), study or concept (4.08%), central meridian in Pacific (4.08%), color (4.08%), symbology (6.12%) and drop shadow near points representing small island developing States (2.04%). **Neutral** responses noted that it was a new or unfamiliar projection (20.41%) and that the color seemed fine (8.16%). Half of respondents who were fine with the colors; however, thought that a greater differentiation could be made. **Negative** responses included comments disliking the projection (10.20%), drop shadow near points representing small island developing States (4.08%) and symbology (2.04%).

**Adjustment** comments included suggestions regarding the color (32.65%), enlarging the points representing the small island developing States (22.45%), adjusting drop shadow near the points representing small island developing States (10.20%), changing the projection (10.20%), experimenting with the unavailable data symbology (4.08%) and adjusting the map scale (2.04%). Four percent thought the legend was far away. **Addition** comments included recommendations to label all small island developing States (8.16%) or to label oceans (2.04%). Suggestions to add toponomy were made, in general or with specific reference to countries or continents (8.16%). Adding interactivity (12.24%) included suggestions of zoom and hover functionality in the map.

#### 4.3.6. No data

Participants were mixed in their response to whether it would be easier to identify small island developing States with unavailable data if the islands without data were represented by a square rather than a circle. Five percent strongly agreed, 37.97% agreed, 20% neither agreed nor disagreed, 34.18% disagreed and 2.53% strongly disagreed. Some noted the visual problem of gray in relation to other color values. One user suggested photocopying the map to see the grayscale to check for perceptibility among those with color deficiency. One participant suggested that, "The percentage information on 'no data' could also be presented in a chart, since it is rather metadata." Suggestions for modifying the point symbol of small island developing States included "adding a bright color" or modifying the outline or stroke of the point to differentiate it from no data.

# 5. DISCUSSION

## 5.1. Online Survey

Following two focus groups and an interview, the online survey evaluated Map D, using the Interrupted Goode Homolosine projection, for effectiveness and satisfaction. An open comments field towards the end of the survey helped to illuminate the resulting percentage of correct responses coupled with ratings of ease.

### 5.1.1. Projection

Eighteen percent of respondents who left comments liked the Interrupted Goode Homolosine projection centered on the Pacific Ocean. And another 18% had a neutral response to the projection, noting that it was “unfamiliar” or “uncommon” or even initially disorienting, but did not suggest changing it. Yet, others indicated this projection might be a concern for a general user (12.24%), and half of those respondents suggested trying another projection. In total 12.24% suggested to try another projection. Ten percent of respondents were categorized as disliking the projection, using descriptions such as “strange” or “awful.” Within these responses one person preferred a “plain world map” and 6.06% disliked the splitting of countries. Another participant asked, “Why not using a rectangle map? (not the globe shape).”

Responses to the Interrupted Goode Homolosine projection were concurrent with differing views on using non-continuous map projections, and the tension between reducing distortion and introducing discontinuities (Canters, 2002). Negative responses indicated a difficulty in interpreting world-wide data, due to the use of an uncommon projection and splitting of countries. The survey questions related to non-island states were thought to be challenging and a likely argument against the map. This confirmed that it would not be an easily interpretable projection to visualize world-wide data. However, it is one suitable for maintaining the geographical regions of small island developing States.

### 5.1.2. Identifying values and distinguishing color

Overall, the highest percentage of feedback related to color, ranging from suggestions of slight adjustments among two classes to dramatic changes, some of which might have been subjective preferences, but overall indicating the colors needed to be easier to distinguish for the points representing small island developing States. In their comments, some participants noted it was difficult to distinguish between the first two classes, while others thought it was difficult to perceive the difference between the gray representing unavailable data and either the first class or the second class, or even both lower classes. A few participants thought the identification of color values was additionally challenging because the legend was far away. Despite the color challenges, approximately 80% of participants were correct in both identifying the poverty rate in the small island developing States of Cabo Verde, which had data in a lower color class, and the Seychelles, which did not have data. Likewise, nearly 20% of respondents noted the map made it difficult (17.24%) or very difficult (2.30%) to answer these questions.

Color perception challenges noted by participants were initially suspected due to external lighting and the monitor’s quality and calibration, especially since trial tests of the survey were conducted on four monitors by varying ages of users without a color issue reported. And indeed, some remarks suggested the color scale was fine: “good colour scale” or “liked the colors.” However, approximately 4% of the population also have color vision impairment (Brewer, 2005). A color scheme was selected through ColorBrewer in consideration of those with vision impairment. Though in hindsight, a sequential color ramp that slightly deviates from a single-hue, referred to on ColorBrewer as a *sequential, multi-hue color scheme*, might have provided more distinct color classes, especially as recommended by ColorBrewer for LCD displays. Given the small point size, it is possible that the color range would be even easier for users if there were greater visual steps between classes than those recommended by ColorBrewer as research did not indicate the size of the colors tested (Harrower & Brewer, 2003). This relates to the comments in Focus group 2, when expert cartographers questioned if perceptibility of classes might be problematic given the size of the point and discerning more than three classes. According to Bertin, only three values may be separable and distinguishable in points (Bertin, 1983). In terms of the color classes, it would also be valuable to test three color classes, which would limit the detail of the data provided, but perhaps enhance the identification of color and the selectivity of regions (Bertin, 1983).

#### 5.1.3. **Comparing color**

Interestingly, when users were asked to compare values of small island developing States, 96.43% answered correctly when comparing a point with the value of the lowest class to that of the second lowest class. One participant mentioned this phenomenon: "It was generally easier to compare two small island nations than identify a specific value in the 5-class scheme, something I would not expect but I guess makes sense in terms of degrees of freedom (e.g., two choices of high low versus five choices of correct category)." While there were only two possible answers for the comparison question, relative to seven potential responses for identification questions, it did require identification of both lighter colors in order to make the comparison.

#### 5.1.4. **Point size**

Increasing the size of the point after the second focus group was done in balance with the representation of the islands in the Caribbean. Approximately 22% of the users thought the point size could be increased. Compared to Focus group 1 and some mention in Focus group 2, the geographic representation of the Caribbean did not receive much comment in the open field other than a response that the "geographic relations are lost" in the proposed solution. Another user wrote, the "Idea of using circles for SIDS is good, but they could be even bigger. Of course, crowding at Caribbean would be worse, but after all Caribbean seems to be a special case anyway. I would say that the presented circles work better in the Pacific."

#### 5.1.5. **Online survey tool**

A contributing factor to perceptibility in the online survey was the maximum width the map image could display, which was less than even the browser's width and consequently reduced the island point size further. In addition, the file size was limited, which reduced the resolution. Unfortunately, this was a restriction of the survey software available. Even though instructions were provided to zoom, some participants noted problems zooming on their browser.

#### 5.1.6. **Outline and drop shadow**

Some participants questioned the use of an outline (or stroke) and drop shadow around the point representing an island. One participant noted that the drop shadow of points changed the perception of color in the fill of a neighboring point or the underlying country with a point. One suggested for perceptibility it should be removed: "…the symbols should follow the guidelines for good information visualization design > no shades, no border and why not make them slightly bigger?" Another user agreed but suggested changing the colors rather than the other graphic treatments: "While the circle outlines & drop shadows helped draw attention to each SIDS, taken together they slightly hindered how efficiently I interpreted the colors (I found it a bit difficult to distinguish between 0-9 and 10-29 color classes). I would change the color scheme rather than remove the outlines/drop shadows."

#### 5.1.7. General search level

Questions regarding the overview of small island developing States were not easy to answer using the map. Only 64.56% of users were able to estimate the percentage of small island developing States without data in the Pacific and only 12.66% of users were able to correctly identify the percentage of small island developing States without data world-wide. Problems with the reduced size of already small points in the browser and difficulty distinguishing values likely contributed to this problem. It would be valuable to reduce the number of classes to three and conduct other evaluations, such as think aloud or eye tracker to see if users were focused on the Pacific when estimating availability of global small island developing State values. Half of the users correctly estimated the percentage of countries missing data world-wide. It was assumed this would not be a helpful map to make estimates and users would not think it was appropriate. It was anticipated that most users would find these questions difficult or very difficult, and while the ease of use did shift more towards difficulty, less than half shared this was the case.

#### 5.1.8. No data

A revision of the point size, outline, drop shadow and color could benefit the ease and accuracy of perceiving the point values. The outline of the point could be used to distinguish small island developing States with and without data. As a participant added: "One possible solution is for the island nations with no data, the circle outline should also be a very pale grey to help differentiate between no data (grey) and data (red scale)." Testing the colors and the gray value of no data would be of interest as guidelines for grayscale representation of no data were not found, other than photocopying the map to check for distinction. Had the classes been reduced to three, it is likely it would have been easier to define a gray value that would have been more distinctive using this method.

Participants slightly favored modifying the design to represent islands without data using a square rather than a circle. Responses might have been more definitive if a visualization was provided to the participant to review. Bertin notes, shape is associative, which would allow squares to be perceived along with circles as representing islands. But shape is not selective, so regions or patterns of missing data would not be possible, only identification of each object (Bertin, 1981). This validates the tension between representing missing data in a similar way as other attribute values or by using other treatments (Kinkeldey et al., 2014; Robinson, 2018).

#### 5.1.9. Toponyms

Small island developing States were labeled on the map if they were a subject of a survey question. If none of the States had toponyms, it would be difficult for many users to identify the countries. If the results of the map indicate a possibility for identification questions to be addressed, the next step would be to provide a label for each State. In static form, perhaps small island developing States might be labeled with a number as suggested by an online survey user or the ISO-alpha3 code could be used in conjunction with a table. This would provide the geographic overview of small island developing States while also helping to identify specific ones. Possibly labeling oceans might help orient some users. This would need to be visually balanced with if and how the States were labelled.

#### 5.1.10. Approval of users

Participation from people living on small island developing States was a smaller sample size than desired (n=4) and not as enthusiastic with the map design to represent small island developing States. Comments from this group were not detailed but did suggest using an inset map or larger symbols and changing colors. Those who had worked on a small island state (n=8) were split in their opinion and those who had lived on a small island state (n=6) responded more positively towards the design. Of the users who noted living on a small island developing State or being from one, the representation was focused in the Caribbean and the Seychelles. Perhaps these users were looking locally and there would have been a more enthusiastic response from users with experience living on or from small islands in the Pacific, where the map centers. Given the scale of the map, the points in the Caribbean either must overlap or use leader lines (or an inset) to be visualized on the available surface of an A3 page. While one user disliked the symbology, representing 2% of responses, 6% liked the symbology and otherwise there were no suggestions to use different shapes to represent the small island developing States, which could indicate the circular point symbol was accepted by users. More than half of the online survey participants thought it was an appropriate map to visualize available and unavailable data of small island developing States.

# 6. CONCLUSION

## 6.1. Summary

Small nations are omitted or difficult to perceive on a small-scale map. Small island developing States are among these nations, comprised of more than fifty States, which may be invisible on a choropleth map displaying global data. While small island developing States are recognized by the United Nations for their social, economic and environmental vulnerabilities, the Sustainable Development Goal indicators, used to track progress towards world-wide social, economic and environmental goals, are often missing data for these States.

To address the imperceptibility of small island developing States in choropleth world maps, this study answered the following research questions.

1. **What visualization approaches exist to map small island developing States and incompleteness of data?**

Static and dynamic visualization approaches were collected and organized into inventories (Appendix C and D). The inventories focused on maps of Sustainable Development Goal indicator data or methods used by international organizations to visualize world-wide data, along with research in geovisualization of uncertainty and on small island developing States. It found the small island developing States were represented with a point symbol or a choropleth value surrounding the toponym in static visualizations. In dense areas, such as the Caribbean, leader lines were used to identify geographic locations of islands. Inset maps or necklace maps were used to augment the perceptibility of small islands. Values of smaller nations might also be listed in a table near the map. The central meridian was set to the Prime Meridian, centered on the Pacific or moved to keep the Pacific islands together. Dynamic maps used magnifying lenses or zooming techniques to enhance the display of the location of interest. Identified projections included Winkel-Tripel, Mercator and Interrupted Goode Homolosine.

Uncertainty visualizations used visual variables extrinsically and intrinsically applied to the maps. Experiments with visualizing uncertainty and incompleteness of data considered visual variables such as the application of hue, saturation, blur, texture, shadow or transparency to represent missing data. Within these solutions, white (or blank) or light gray to represent no data is included. Most of these approaches were static, but some dynamic ones highlighted the borders of countries without data or suggested there might be a swiping, drain or explosion to draw attention to missing data.

2. **How can small island developing States be visualized in insightful ways using available Sustainable Development Goal indicator data?**
    - **What are the spatial characteristics of small island developing States?**
    - **What is the nature of Sustainable Development Goal indicator data?**
    - **What is the quality stamp for the tier categories of selected Sustainable Development Goal indicator(s) and what do these mean?**

The United Nation designates the regions of small island developing States into three categories: Atlantic, Indian Ocean, Mediterranean and South China Sea (AIMS), Caribbean Sea and Pacific Ocean (Appendix A). Small island developing States were defined in this study as 52 entities (Appendix B). Small island developing States include a few non-island states, such as Belize, Guyana, Suriname and Guinea-Bissau. Other States may consist of one island or many tiny islands. Small island developing States were identified with a point symbol and, in one instance, labeled with ISO-alpha3 codes. If the landmass of the island was too small to completely surround the point symbol, the island was removed, and the point symbol represented the State.

Sustainable Development Goal indicator data was analyzed based on tier categories for completeness, including its availability of data for small island developing States. The United Nations categorizes Sustainable Development Goal indicator data into three tiers. As of 11 May 2018, there are 92 Tier I indicators, representing the highest quality of indicators, which contain data available for at least fifty percent of countries and of the population in the region. There are 72 Tier II indicators, which have data inconsistently provided by nations. Some Tier II indicators were not made available by the United Nations. The remaining 62 Tier III indicators are in progress of formalizing standards and methodology; therefore, none were available for review. There are five indicators that are a combination of tiers. Most Sustainable Development Goal indicators used a percentage of (sub)population data type. Sustainable Development Goal indicator data was sparse for small island developing States. Indicator 1.1.1 *Proportion of population below the international poverty line, by sex, age, employment status and geographical location (urban/rural)* was a Tier I indicator that had data available for 138 countries including 21 of the 52 small island developing States.

Of the five static visualizations that were proposed, two gave an overview of global data with the inclusion of small island developing States as color-value points or color-value ISO-alpha3 codes. These represent alternatives which combine familiar projections, such as Mercator and Winkel-Tripel, with alternative graphic treatments for the representation of small island developing States and kept the Pacific islands together in one region. These visualizations used leader lines to identify islands in the Caribbean, which maintained their geographic distribution but altered the location of the point or ISO-alpha3 code that described the island.

Two other proposed maps used the Winkel-Tripel projection and minimized the world overview to enhance the visualization of small island developing States with magnifying lens and inset solutions. These increased the point size representing the small island developing States and preserved the geographic distribution of Caribbean islands, though split the representation of the islands into four regions using two scales. The fifth visualization used the Interrupted Goode Homolosine projection centered in the Pacific, forfeiting the visualization of non-island values to suit the geographic distribution of small island developing States. Leader lines identified the position of Caribbean islands. These five visualizations increased the perceptibility of small island developing States.

3. **How do users interpret the visualization of small island developing States (and inclusion of missing attribute data)?**
    - **Which evaluation methods are to be used to understand which maps are preferred by users?**
    - **Which representations are preferred by users? Why?**
    - **Which representations communicate attribute values of small island developing States with clarity?**

A representative from a small island developing State in the Caribbean and two focus groups evaluated the visualizations to provide qualitative feedback on five static designs which informed the selection and revision of the maps before an online survey of one map was conducted. The interview and focus groups captured reactions and preferences of users. The online survey evaluated for correctness and satisfaction.

Participants in the initial focus group were attracted to the magnifying lens solution, and while the Mercator projection was familiar, they recognized it was not the optimal projection for global data. Even though they were more comfortable with the Winkel-Tripel projection, most participants saw value in the Interrupted Goode Homolosine projection to focus on the small island developing States. Part of the discomfort felt by users was mitigated by revising the map to provide clearer orientation cues through the equator and antemeridian in the second focus group. However, a small proportion of users did not like the interrupted projection, in general. This was confirmed in the expert focus group with one person interested in a non-interrupted projection and in the online survey responses which included 12% suggesting to use another projection, 10% disliking the projection and 6% disliking the splitting of landmasses. In discussing the magnifying solution using the Winkel-Tripel projection and the Interrupted Goode Homolosine projection, most of the expert cartographers in the second focus group preferred the Interrupted Goode Homolosine projection for its overview of the geographic distribution of small island developing States.

After the second focus group, the Interrupted Good Homolosine map was evaluated through an online survey for correctness and satisfaction. Eighty-percent of respondents correctly answered elementary questions to identify the value of a small island developing State and identify that another States was missing data. Ninety-six percent of participants correctly compared small island developing State values. This suggests that the map can be used to identify and compare values of specific islands, though it is likely that labeling would be required. However, participants had more difficulty estimating the percentage of small island developing States missing data within a region and within the world-wide context, which means the map would not be suitable to provide regional or global overviews in its current format. Without related text for the map, participants wondered why there was a map of missing data, especially if the focus was on the small island developing States which had approximately 60% missing data. Participants were mixed on the squares representing islands without data, though users preferred circular point symbols to ISO-alpha3 codes to visualize small islands. Interestingly, nearly all users accepted circular point symbols without comment, suggesting it is an intuitive solution to represent small island data in choropleth maps. The expert focus group's preference of the visualization using the Interrupted Goode Homolosine projection was confirmed by more than half of the online survey respondents who were supportive of the map's appropriateness to visualize available and unavailable indicator data of small island developing States.

## 6.2. Limitations and recommendations

This study represents an investigation of alternative visualizations that specifically address small island developing States in small-scale, choropleth maps. Points to consider in the creation of these maps and this study:

- **Projection** – while less familiar, the Interrupted Goode Homolosine projection is an equal-area projection ideal for representing statistical data. It focuses on ocean regions, which inhibits the ease with which users interpret non-island data but shows the geographic representation of islands. Some may have adverse reactions to the projection because it is interrupted or unfamiliar.

- **Island representation** – there are additional island states that were not included in this study, which would add to the visual complexity of the map. The data of some small island developing States are linked to Sovereign state values, making the associated data value potentially incongruent with the sole reality of the island state.

- **Spatial distribution** – leader lines were used to identify the dense positioning of the Caribbean islands at a small scale. Alternatives suggested in the study included increasing the point size and allowing the islands to overlap or increasing the scale of one lobe to represent Caribbean islands without leader lines.

- **Classes and color values** – while users were able to identify island values in the five-class color scheme, further evaluation would advantageous with a more complete set of available data classes in distinct colors. If the class size were reduced to three, the data would likely be representative in each of the three classes rather than the broader range of five. A three-class color scheme would likely provide regional and world-wide overviews of data since three classes would permit selectivity in point symbols. In this regard, three classes would be suitable for a visualization which does not use toponyms but provides regional and global overviews of small island developing State data.

- **No data** – given the missing indicator data for many small island developing States, the Sustainable Development Goal indicators would be appropriate to use in future studies dedicated to alternatives representation of missing data. However, responses to the missing data may differ based on the amount of data missing and the spatial patterns of missing data. There are more alternatives to test such as a bright, saturated hue to represent missing data. A different treatment to the stroke around the point could help differentiate the missing data from other attribute values, though given the point size, not all solutions for missing data may be possible or advisable.

- **Outline and drop shadow** – the width and color of the stroke around the point and intensity of the drop shadow are additional graphic treatments to be tested.

- **Toponyms** – even with geographic knowledge of island regions, with the shape of the islands replace to a point, the identification of islands would be easier if labelled. This would be particularly pertinent if the primary focus of the map was to answer identification questions.

- **Use and users** – the use case and users of these maps are broad. If these were explored in more depth, it might influence the design of the map.

- **Reproducibility** – the workflow to create these maps has limited reproducibility. Using leader lines to point to the Caribbean islands is a manual process. Points require displacement in the Caribbean and Pacific.

- **Online survey** – the survey tool did not permit a full view of the map in the browser. Color considerations are less controllable in an online environment. Classes need to be reduced or values between classes need to be perceptually more distinctive.

With these recommendations in mind, this study offers solutions to increase the perceptibility of small island developing States in small-scale, choropleth maps.

### 6.3. Next phase

Many of the challenges noted in this study could be addressed through a dynamic visualization. An interactive solution might allow the user to shift the central meridian to change the visualization between the Interrupted Goode Homolosine projection focused on oceans to one focused on landmasses. Similarly, it might be possible to change projections between the Interrupted Goode Homolosine to a more familiar or uninterrupted projection, preferred by some users, such as the Winkel-Tripel. Similarly, it would be advantageous to permit the user to shift the central meridian in this visualization to view island regions, such as in the Pacific as one area.

Given the size of many small island developing States, an interactive visualization would still require a point symbol to identify the attribute value of the island. It could be possible to select all small island developing States to be highlighted or otherwise identified. In the case of the Caribbean, another symbolic identifier might be needed to indicate there is more data to view in this dense island region. Dynamic solutions could provide a lens to magnify small island developing States and functionality to zoom to small island regions, search for a specific island and identify an island with a tooltip. In these cases where the scale shifts in an interactive map, the size of the circle representing the island and eventual view of the island's boundary would need to be determined.

Color and classes have the potential to be further explored in the map. Establishing a distinguishable set of colors for available data which also has sufficient contrast from the representation of missing data is crucial. A maximum of three classes would be recommended if the purpose is to provide overview on the global or regional patterns of small island developing State data. Five color classes could be considered to use in an interactive map for identification of island values. Regional and world-wide overviews might be possible in an interactive map if a class selected in the legend resulted in the highlighting of point symbol outlines or national boundaries. This could permit selectivity on a class-by-class basis in a five-class range. It would also initiate an examination of visual treatment between the point outlines of islands and boundaries of non-islands.

Unavailable data could be differentiated from available data by using a point with gray value fill and a stroke (or outline) in a lighter gray. Alternatively, unavailable data could be highlighted using a bright, saturated color, when missing data is selected to view. It is also possible that gaps in the attribute data might be filled through data from prior years and the symbols proposed in this study could be used to visualize the recency of data as it relates to certainty. Another advantage to the dynamic visualization would be that the code could be shared, and indicator datasets could be added and updated, aiding in reproducibility and recency of the visualization. Sustainable Development Goal indicators could also be reviewed in succession. These solutions could also extend to other datasets to create geographic visualizations that are more inclusive of small island developing States.

This initial study offers approaches to increase the perceptibility of small island developing States in static, small-scale choropleth maps and contributes to the visualization of certainty in global status towards reaching Sustainable Development Goals.

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# APPENDICES

**Appendix A – Listing of small island developing States on UN Sustainable Development Knowledge Platform (DESA - UN, 2018b)**

## Small Island Developing States

### UN MEMBERS (37)

#### Atlantic, Indian Ocean, Mediterranean and South China Sea (AIMS) (8)

Cabo Verde
Comoros
Guinea-Bissau
Maldives
Mauritius
Sao Tomé and Principe
Seychelles
Singapore

#### Caribbean (16)

Antigua and Barbuda
Bahamas
Barbados
Belize
Cuba
Dominica
Dominican Republic
Grenada
Guyana
Haiti
Jamaica
Saint Kitts and Nevis
Saint Lucia
Saint Vincent and the Grenadines
Suriname
Trinidad and Tobago

#### Pacific (13)

Fiji
Kiribati
Marshall Islands
Micronesia (Federated States of)
Nauru
Palau
Papua New Guinea
Samoa
Solomon Islands
Timor-Leste
Tonga
Tuvalu
Vanuatu

### NON-UN MEMBERS/ASSOCIATE MEMBERS OF REGIONAL COMMISSIONS (20)

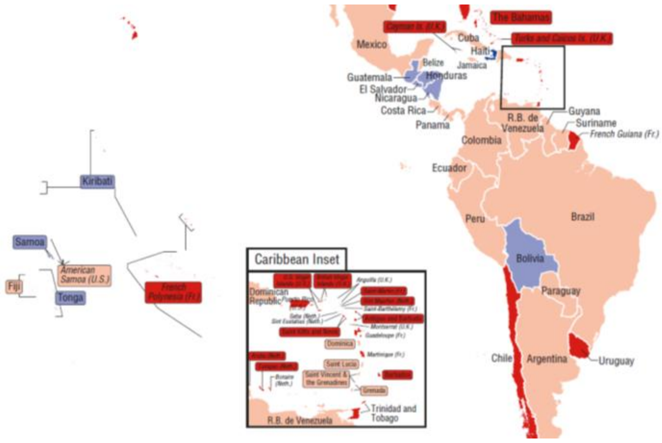
American Samoa
Anguilla
Aruba
Bermuda
British Virgin Islands
Cayman Islands
Commonwealth of Northern Marianas
Cook Islands
Curacao
French Polynesia
Global Partnership for Effective Development Co-operation (GPEDC)
Guadeloupe
Guam
Martinique
Montserrat
New Caledonia
Niue
Puerto Rico
Sint Maarten
Turks and Caicos Islands
U.S. Virgin Islands

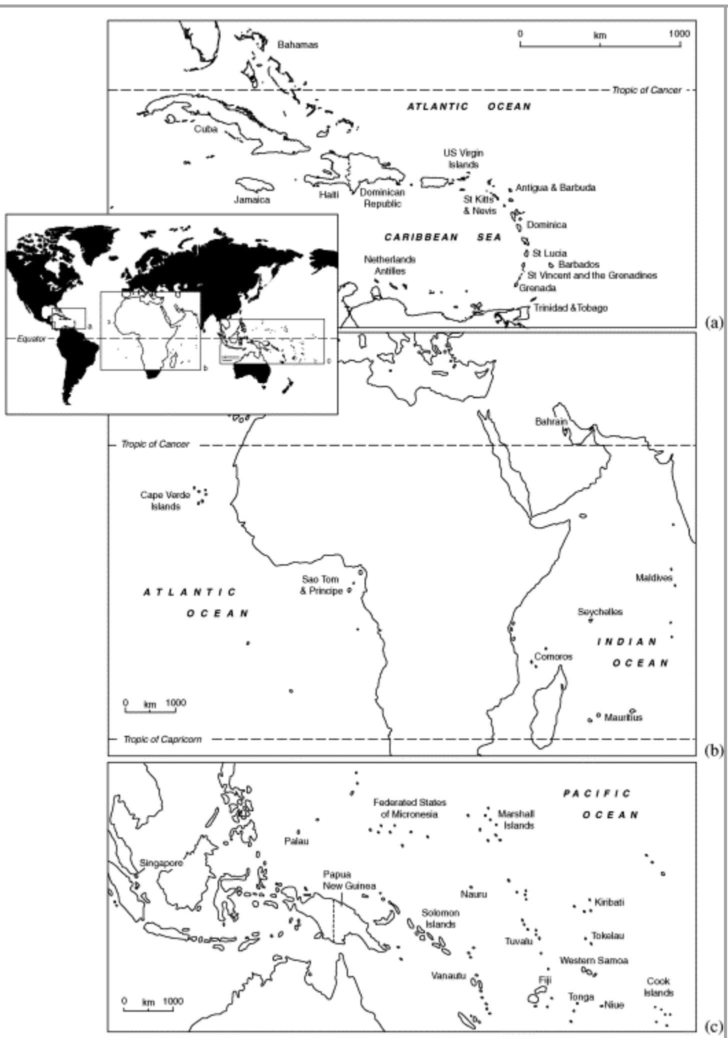
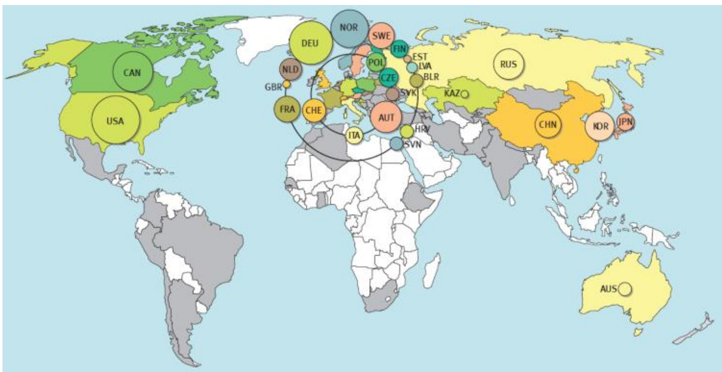
## Appendix B – Table of small island developing States

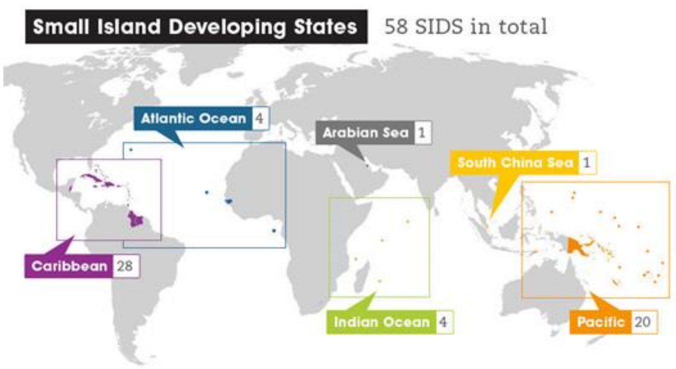
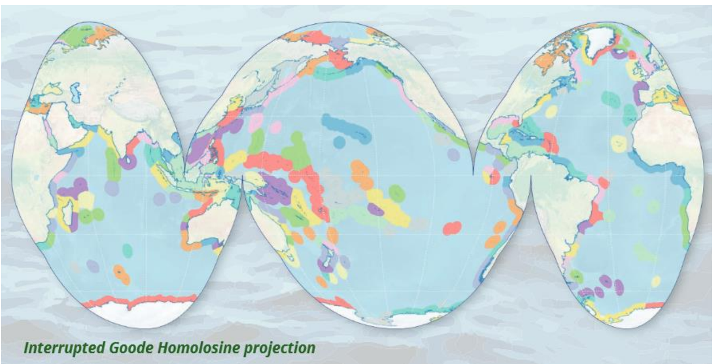
| Country or Area Name | Membership type | Full member sub-group | Area Code | ISO-alpha3 Code |
|---|---|---|---|---|
| American Samoa | Non-UN or Associate | --- | M49_OCE_POL | ASM |
| Anguilla | Non-UN or Associate | --- | MDG_LAC_CAR | AIA |
| Antigua and Barbuda | Full | Caribbean | MDG_LAC_CAR | ATG |
| Aruba | Non-UN or Associate | --- | MDG_LAC_CAR | ABW |
| Bahamas | Full | Caribbean | MDG_LAC_CAR | BHS |
| Barbados | Full | Caribbean | MDG_LAC_CAR | BRB |
| Belize | Full | Caribbean | M49_LAC_CA | BLZ |
| British Virgin Islands | Non-UN or Associate | --- | MDG_LAC_CAR | VGB |
| Cabo Verde | Full | AIMS | M49_AFR_WA | CPV |
| Commonwealth of Northern Marianas | Non-UN or Associate | --- | M49_OCE_MIC | MNP |
| Comoros | Full | AIMS | M49_AFR_EA | COM |
| Cook Islands | Non-UN or Associate | --- | M49_OCE_POL | COK |
| Cuba | Full | Caribbean | MDG_LAC_CAR | CUB |
| Curacao | Non-UN or Associate | --- | MDG_LAC_CAR | CUW |
| Dominica | Full | Caribbean | MDG_LAC_CAR | DMA |
| Dominican Republic | Full | Caribbean | MDG_LAC_CAR | DOM |
| Fiji | Full | Pacific | M49_OCE_MEL | FJI |
| French Polynesia | Non-UN or Associate | --- | M49_OCE_POL | PYF |
| Grenada | Full | Caribbean | MDG_LAC_CAR | GRD |
| Guam | Non-UN or Associate | --- | M49_OCE_MIC | GUM |
| Guinea-Bissau | Full | AIMS | M49_AFR_WA | GNB |
| Guyana | Full | Caribbean | M49_LAC_SA | GUY |
| Haiti | Full | Caribbean | MDG_LAC_CAR | HTI |
| Jamaica | Full | Caribbean | MDG_LAC_CAR | JAM |
| Kiribati | Full | Pacific | M49_OCE_MIC | KIR |
| Maldives | Full | AIMS | MDG_SAS | MDV |
| Marshall Islands | Full | Pacific | M49_OCE_MIC | MHL |
| Mauritius | Full | AIMS | M49_AFR_EA | MUS |
| Micronesia (Federated States of) | Full | Pacific | M49_OCE_MIC | FSM |
| Montserrat | Non-UN or Associate | --- | MDG_LAC_CAR | MSR |
| Nauru | Full | Pacific | M49_OCE_MIC | NRU |
| New Caledonia | Non-UN or Associate | --- | M49_OCE_MEL | NCL |
| Niue | Non-UN or Associate | --- | M49_OCE_POL | NIU |
| Palau | Full | Pacific | M49_OCE_MIC | PLW |
| Papua New Guinea | Full | Pacific | M49_OCE_MEL | PNG |
| Puerto Rico | Non-UN or Associate | --- | MDG_LAC_CAR | PRI |
| Saint Kitts and Nevis | Full | Caribbean | MDG_LAC_CAR | KNA |
| Saint Lucia | Full | Caribbean | MDG_LAC_CAR | LCA |
| Saint Vincent and the Grenadines | Full | Caribbean | MDG_LAC_CAR | VCT |
| Samoa | Full | Pacific | M49_OCE_POL | WSM |
| Sao Tome and Principe | Full | AIMS | M49_AFR_MA | STP |
| Seychelles | Full | AIMS | M49_AFR_EA | SYC |
| Singapore | Full | AIMS | MDG_SEAS | SGP |
| Sint Maarten | Non-UN or Associate | --- | MDG_LAC_CAR | SXM |

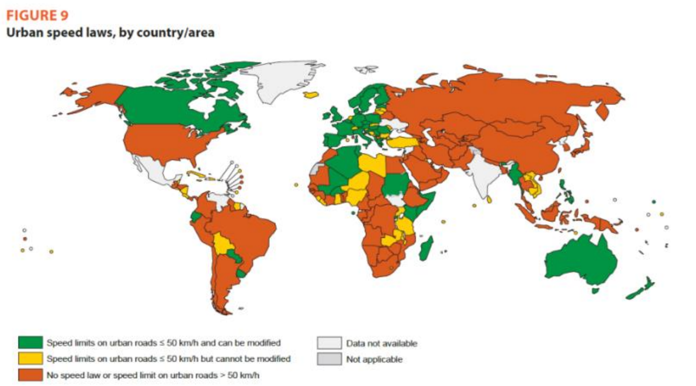
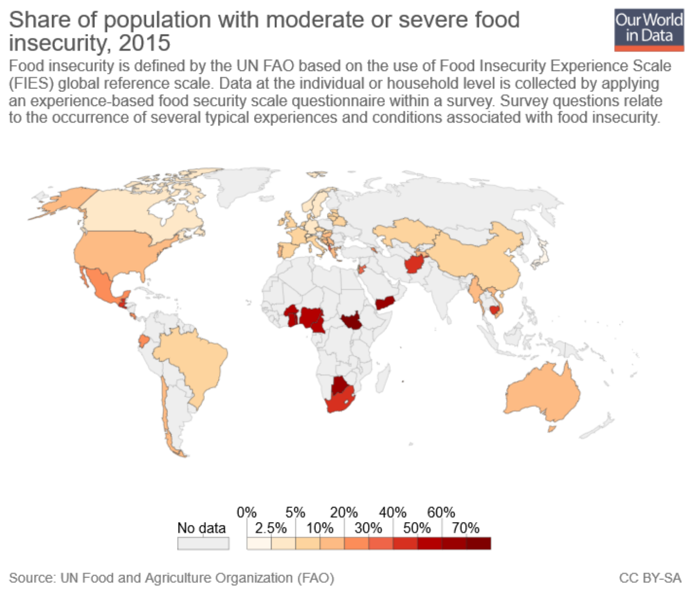
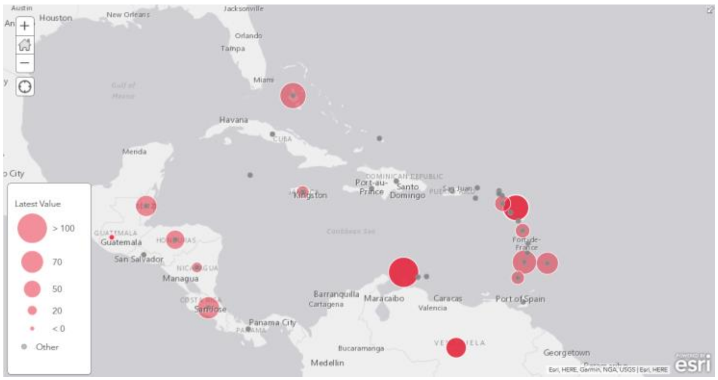
| | | | | |
|---|---|---|---|---|
| Solomon Islands | Full | Pacific | M49_OCE_MEL | SLB |
| Suriname | Full | Caribbean | M49_LAC_SA | SUR |
| Timor-Leste | Full | Pacific | MDG_SEAS | TLS |
| Tonga | Full | Pacific | M49_OCE_POL | TON |
| Trinidad and Tobago | Full | Caribbean | MDG_LAC_CAR | TTO |
| Tuvalu | Full | Pacific | M49_OCE_POL | TUV |
| U.S. Virgin Islands | Non-UN or Associate | --- | MDG_LAC_CAR | VIR |
| Vanuatu | Full | Pacific | M49_OCE_MEL | VUT |

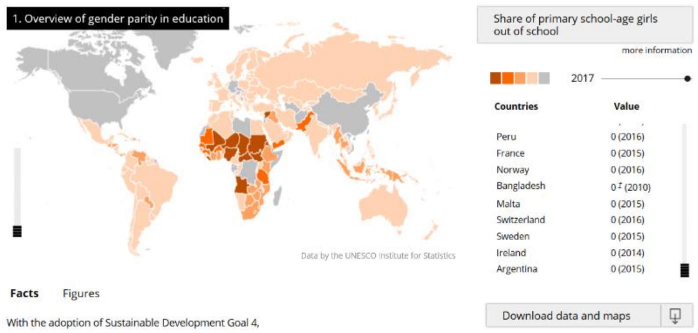
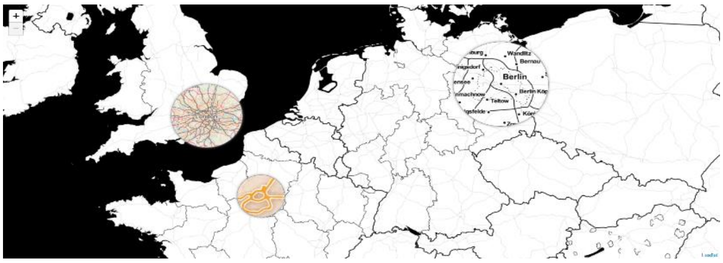
## Appendix C – Inventory of small island developing States maps

| Organization or researcher | Map | Notes |
|---|---|---|
| STATIC | | |
| World Bank (2017)<br>*SDG Atlas*<br>http://datatopics.worldbank.org/sdgatlas/ |  | • Leader line annotations and inset maps for two-page spreads<br>• Smaller maps on single pages, no toponyms |
| UNISDR (2017)<br>*GAR Atlas*<br>https://www.unisdr.org/we/inform/publications/53086 |  | • Listing of SIDS with corresponding choropleth values in rounded corner rectangle next to each country name<br>• List set in Pacific Ocean |

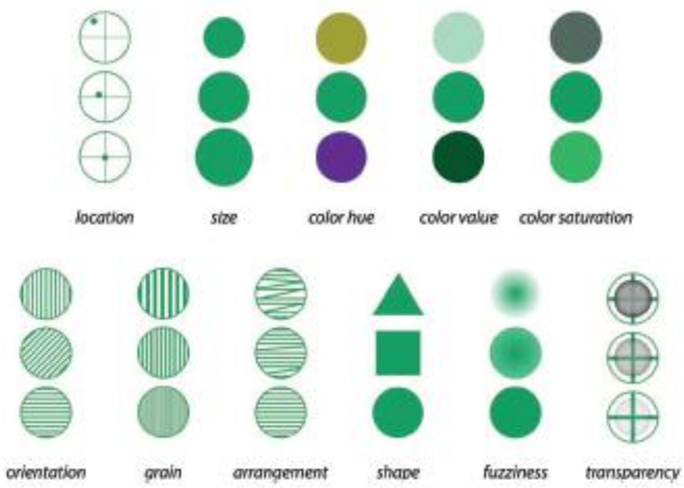
| | | |
|---|---|---|
| Pelling, M. & Uitto, J. (2001) *Small island developing states: natural disaster vulnerability and global change.* Global Environmental Change Part B: Environmental Hazards. |  | • Outdated/not conforming to current SIDS categories<br>• Scale difference between Caribbean and other two regions<br>• Toponyms for SIDS<br>• No country boundaries except for SIDS |
| Speckmann, B. & Verbeek, K. (2010) *Necklace Maps.* IEEE Transactions on Visualization and Computer Graphics. |  | • Abbreviations for toponyms<br>• Can have more than one "necklace" per country or continent (and authors believe more than one is needed in general) |

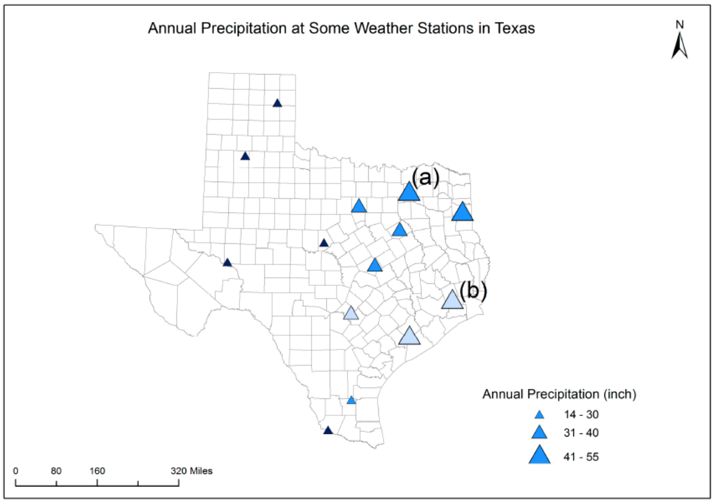
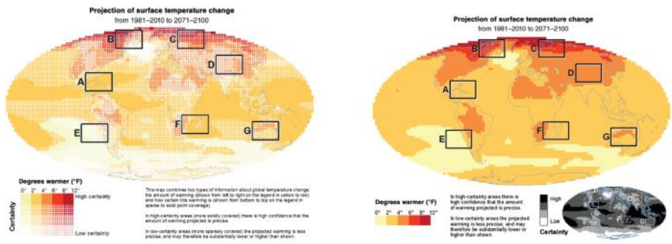
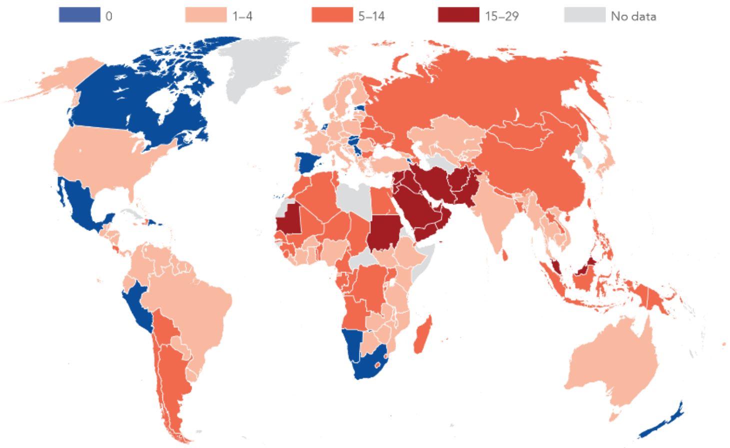
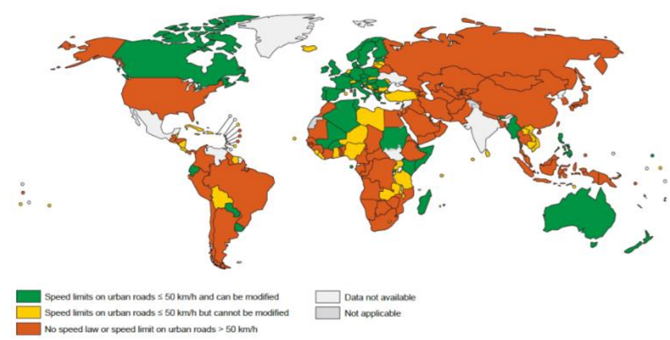
| | | |
|---|---|---|
| SciDev.Net (2014) *Ocean science for development in SIDS: Facts and figures* https://www.scidev.net/global/water/feature/ocean-science-development-sids-facts-figures.html |  | • Outdated/not conforming to current SIDS categories<br>• Possible inset groupings |
| SciDev.Net (2014) *Ocean science for development in SIDS: Facts and figures* https://www.scidev.net/global/water/feature/ocean-science-development-sids-facts-figures.html |  | • Points to represent smaller islands even in inset<br>• Some leader lines |
| Osiris (2013) https://commons.wikimedia.org/wiki/File:SIDS_map_en.svg |  | • Outdated/not conforming to current SIDS categories<br>• Fanned leader lines to label Caribbean SIDS |
| ICA Commission on Map Projections *SDG Goal 15: Life on land poster* https://icaci.org/files/developmentgoals/goal_15.pdf |  | • Projection focuses on oceans and distribution of islands |

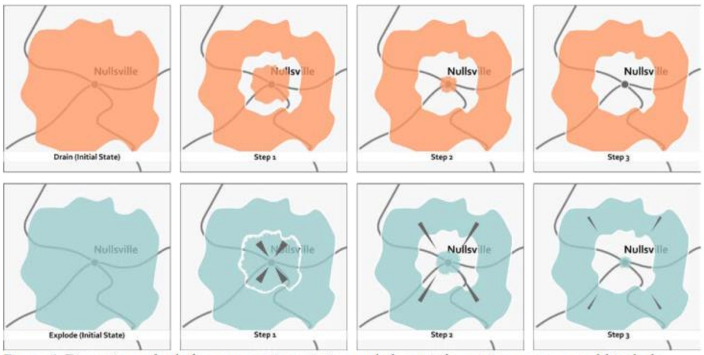
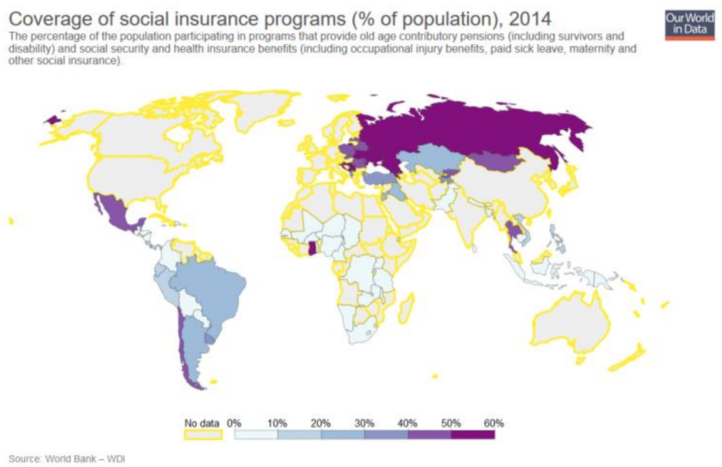
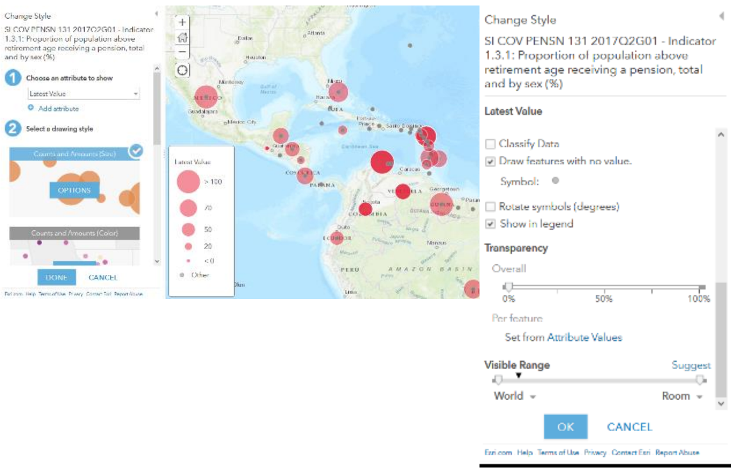
| | | |
|---|---|---|
| WHO (2015)<br>*Global Status Report on Road Safety*<br>http://www.who.int/violence_injury_prevention/road_safety_status/2015/en/ |  | • Fanned leader lines to label Caribbean SIDS with colored point to represent choropleth value<br>• Not all SIDS included (for example Caribbean) |
| DYNAMIC | | |
| Our World in Data<br>*SDG Tracker*<br>https://sdg-tracker.org |  | • Hover; possible to see Haiti and Dominican Republic values but many other SIDS values missing with hover functionality<br>• No zoom |
| UNSD<br>*Open SDG Data Hub*<br>https://www.arcgis.com/home/webmap/viewer.html?panel=gallery&suggestField=true&url=https%3A%2F%2Fservices7.arcgis.com%2Fgp50Ao2knMIOM89z%2Farcgis%2Frest%2Fservices%2FSI_COV_PENSN_131_2017Q2G01%2FFeatureServer%2F0 |  | • Zoom to see SIDS<br>• Pan<br>• Click to select country info<br>• Search field to find country |

| | | |
|---|---|---|
| UNESCO Institute for Statistics (UIS) *eAtlas series (TellMaps)* https://tellmaps.com/uis/gender/#!/tellmap/-1195952519 |  | ● Manual zoom with slider to see SIDS<br>● Pan<br>● Scrollable and selectable list of countries (functionality to click on country in list and map zooms to country) |
| Leaflet http://bbecquet.github.io/Leaflet.MagnifyingGlass/examples/example_multi.html |  | ● Zoom<br>● Static magnifying lens that zooms to another tile level along with main zoom<br>● Can set scale of each magnifying glass at different zoom levels |

## Appendix D – Inventory of incompleteness of data in maps

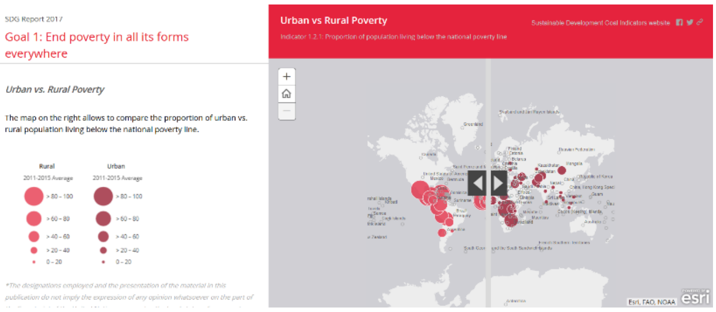
| **Organization or researcher** | **Map** | **Notes** |
|---|---|---|
| STATIC | | |
| MacEachren, et al. (2012)<br>*Visual Semiotics and Uncertainty Visualisation: An Empirical Study* | <br> | • Visual variables to communicate the degree of certainty |
| Robinson, A.C. (2018)<br>*Representing the Presence of Absence in Cartography* | <br> | • Intrinsic approach<br><br>+ hue<br>+ saturation<br>+ blur<br><br>~ texture (even more troublesome than hue with scale/area for countries)<br>~ shadow (same issue)<br><br>- value (difficult to distinguish in choropleth map)<br>- transparency (difficult to distinguish in choropleth map) |

<table>
<tr>
<td>Scholz & Lu (2014)<br>Uncertainty in Geographic Data on Bivariate Maps: An Examination of Visualization Preference and Decision Making</td>
<td>
</td>
<td>● Extrinsic uncertainty visualization approach</td>
</tr>
<tr>
<td>Retchless & Brewer (2015)<br>Guidance for representing uncertainty on global temperature change maps</td>
<td>
</td>
<td>● Uncertainty visualization of continuous data using small-scale world maps<br>● Coincident (bivariate) and adjacent example</td>
</tr>
<tr>
<td>World Bank (2017)<br>SDG Atlas<br>http://datatopics.worldbank.org/sdgatlas/</td>
<td>
</td>
<td>● Light gray (no data) and blue for “0”</td>
</tr>
<tr>
<td>WHO (2015)<br>Global Status Report on Road Safety<br>http://www.who.int/violence_injury_prevention/road_safety_status/2015/en/</td>
<td>FIGURE 9<br>Urban speed laws, by country/area<br>
</td>
<td>● Two gray values; lighter gray (no data) difficult to distinguish between the two values on map</td>
</tr>
</table>

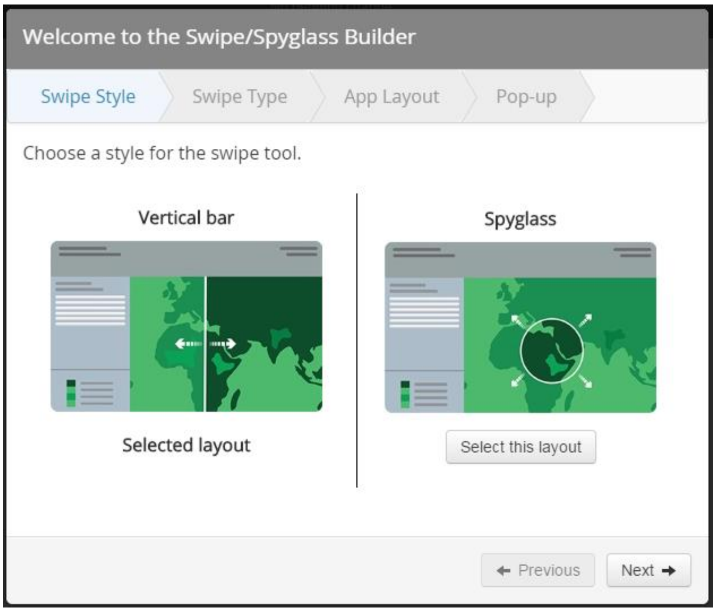
| DYNAMIC | | |
|---|---|---|
| Robinson, A.C. (2018)<br>*Representing the Presence of Absence in Cartography* | <br>Figure 6. Dynamic methods for representing missing and absent information on maps could include using drain (at top) and/or explosion (at bottom) effects. | • Drain (top) or Explode effects<br>• Suggested but not developed yet<br>• Other dynamic approaches suggested by Robinson based on (Lobo, Pietriga, & Appert, 2015): (1) juxtaposition (2) translucent overlay (3) swipe (4) lenses |
| Our World in Data<br>*SDG Tracker*<br>https://sdg-tracker.org |  | • No data (light gray)<br>• When no data is selected in legend, yellow outline appears around countries without data (this happens for every category of values selected in legend)<br>• Hover over countries with data and label appears, including date if it is not the most recent year<br>• Hover over "no data" countries = no label |
| UNSD<br>*Open SDG Data Hub*<br>https://www.arcgis.com/home/webmap/viewer.html?panel=gallery&suggestField=true&url=https%3A%2F%2Fservices7.arcgis.com%2Fgp50Ao2knMIOM89z%2Farcgis%2Frest%2Fservices%2FSI_COV_PENSN_131_2017Q2G01%2FFeatureServer%2F0 |  | • No value = "other" (gray dot)<br>• Option to toggle to show "no values"<br>• Selected country values appear on click (info box pulled from database, for ex. every year noted) |

<table>
<tr>
<td>UNESCO Institute for Statistics (UIS)<br>*eAtlas series (TellMaps)*<br>https://tellmaps.com/uis/gender/#!/tellmap/-1195952519</td>
<td>
</td>
<td>

- No data (gray)
- Scrollable list of countries, including "0", omitting "NA"
- Hover provides name of country (+value and year for those with value, otherwise empty)

</td>
</tr>
<tr>
<td>UNDESA<br>United Nations Department of Economic and Social Affairs<br>*SDG Report 2017*<br>https://undesa.maps.arcgis.com/apps/MapSeries/index.html?appid=9f608346a69644c387ddc9df29f12b43</td>
<td>
</td>
<td>

- Point (gray outline, no fill) for country + toponym, including countries without data, including SIDS, which makes it clustered and difficult to read in the Caribbean at the default view

</td>
</tr>
<tr>
<td>Esri Story Maps<br>https://storymaps.arcgis.com/en/app-list/swipe-spyglass/tutorial/</td>
<td>
</td>
<td>

- Vertical bar or spyglass could be used to reveal the incompleteness of attribute data

</td>
</tr>
</table>

## Appendix E – Selection of Sustainable Development Goal Indicators

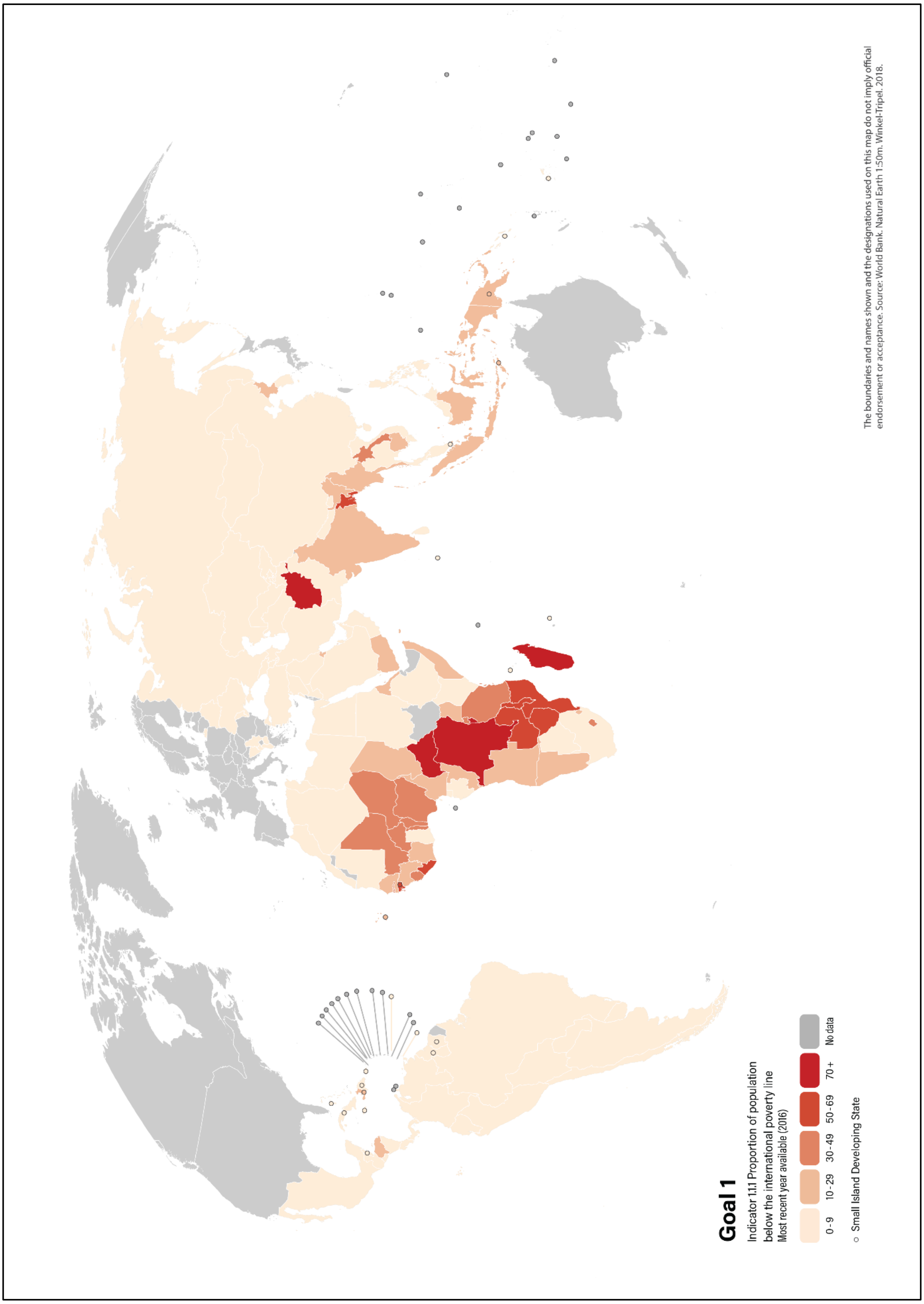
| Indicator | Indicator description | Tier | Data type | Thematic link | Subsection of data | Most recent year | Completeness |
|---|---|---|---|---|---|---|---|
| 1.1.1 | Proportion of population below the international poverty line, by sex, age, employment status and geographical location (urban/rural) | I | Percent of (sub)population | inequality (poverty) | 15 years old and over, both sexes or no breakdown by sex, 2016 | 2016 | 2016: 137 countries;<br>much more complete and somewhat more recently collected compared to indicator 1.2.2<br>21 SIDS |
| 1.2.1 | Proportion of population living below the national poverty line, by sex and age | I | Percent of (sub)population | inequality (poverty) | urban/rural sparsely available | 2015 | INCOMPLETE<br>All area: 18 available in 2015<br>Rural/Urban: 8/7 in 2015<br><br>consider using "most recent data available," spanning 1993-2015, if dataset is used at all |
| 3.c.1 | Health worker density and distribution | I | Rate of two variables; dentist, nurse/midwife, pharmaceutical, doctor<br>per 1,000 population | inequality (health)<br><br>Target directly names SIDS | nurse/midwife or doctor, 2014 | 2015 | nurse/midwife: 8 countries in 2015; 62 in 2014<br>doctor: 10 countries in 2015; 71 in 2014<br>dentist: 71 in 2014<br>pharmaceutical: 62 in 2014 |
| 4.2.2 | Participation rate in organized learning (one year before the official primary entry age), by sex | I | Percent of (sub)population | inequality (education) | male/female/total, 2015 | 2016, yet only 8 countries available; refer to 2015 | 79 countries in 2015<br>8 countries in 2016 |
| 5.4.1 | Proportion of time spent on unpaid domestic and care work, by sex, age and location | II | Proportion of time by (sub)population | inequality (labor) | male/female, 2015 (incomplete) OR most recent data available, 2000-2015 | 2015 | INCOMPLETE<br>M/F percentages: 5 countries in 2015<br>Most recent data available (2000-2015): 72 countries |
| 5.5.1 | Proportion of seats held by women in (a) national parliaments ~~and (b) local governments~~ | I (a)/ ~~II (b)~~ | Percent of (sub)population | inequality (gender) | National, 2017 | 2017 | Nearly complete; (b) local governments unavailable<br>37 SIDS |
| 6.1.1 | Proportion of population using safely managed drinking water services | II | Percent of (sub)population | inequality (water) | Total, 2015 | 2015 | 2015 total: ~105 countries; 20 rural; 50 urban<br>4 SIDS available |
| 16.3.2 | Unsentenced detainees as a proportion of overall prison population | I | Percent of (sub)population | inequality (justice) | 2015 | 2015<br>Prior year available: 2005 | 2015: 143 countries<br>24 SIDS |

Appendix F – Output of Python script to summarize indicators

```
--- SUMMARY OF C010101.csv ---
Age group: 15 years old and over
Sex: Both sexes or no breakdown by sex
Year: 2016

Total countries in output: 137
Contain zero: 10
Contain NaN: 0

Countries missing:
ABW
AIA
ALA
AND
ANT
ASM
ATA
ATF
…

--- END OF SUMMARY ---
```

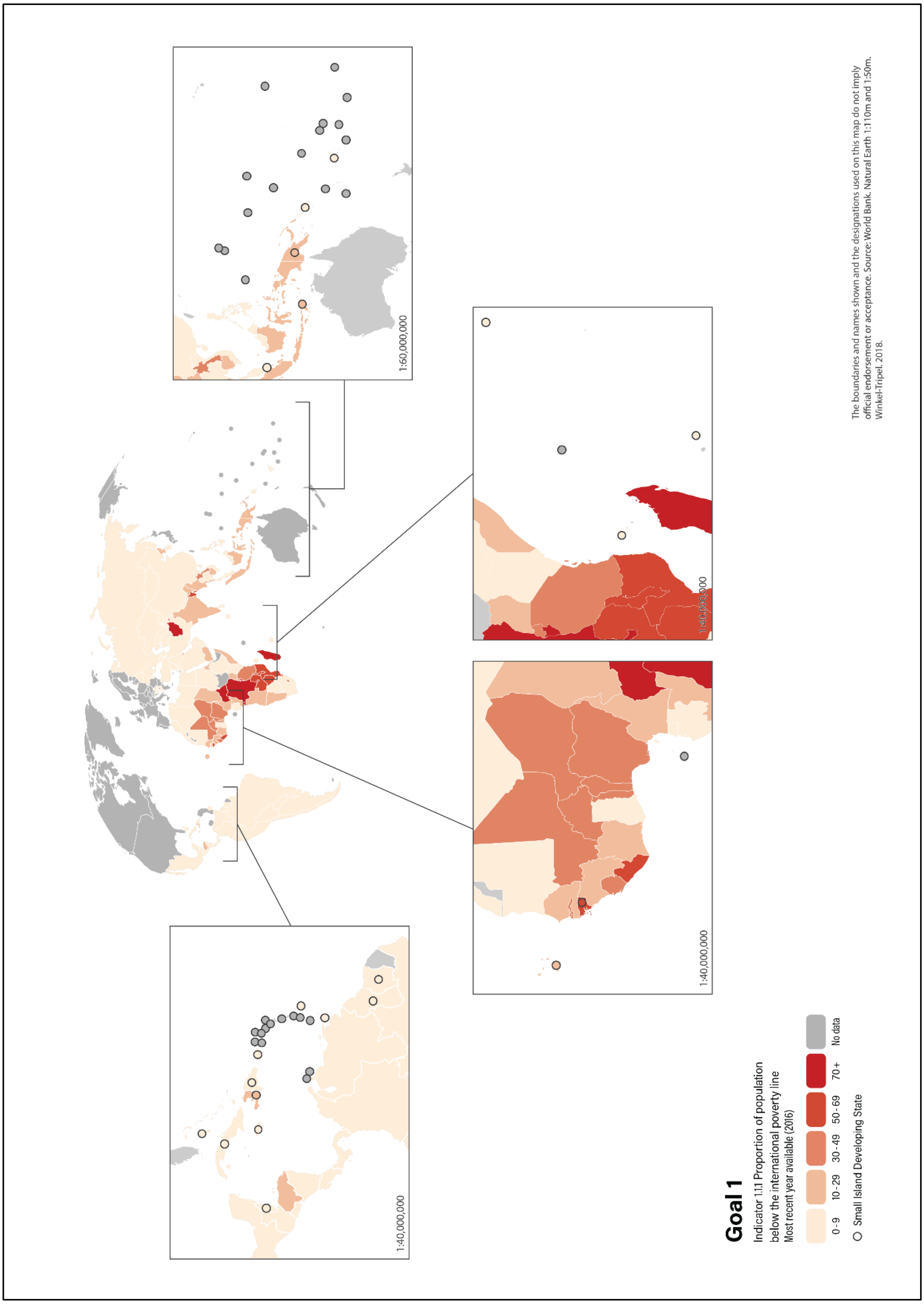
**Appendix G – Proposed map designs**

## Map A



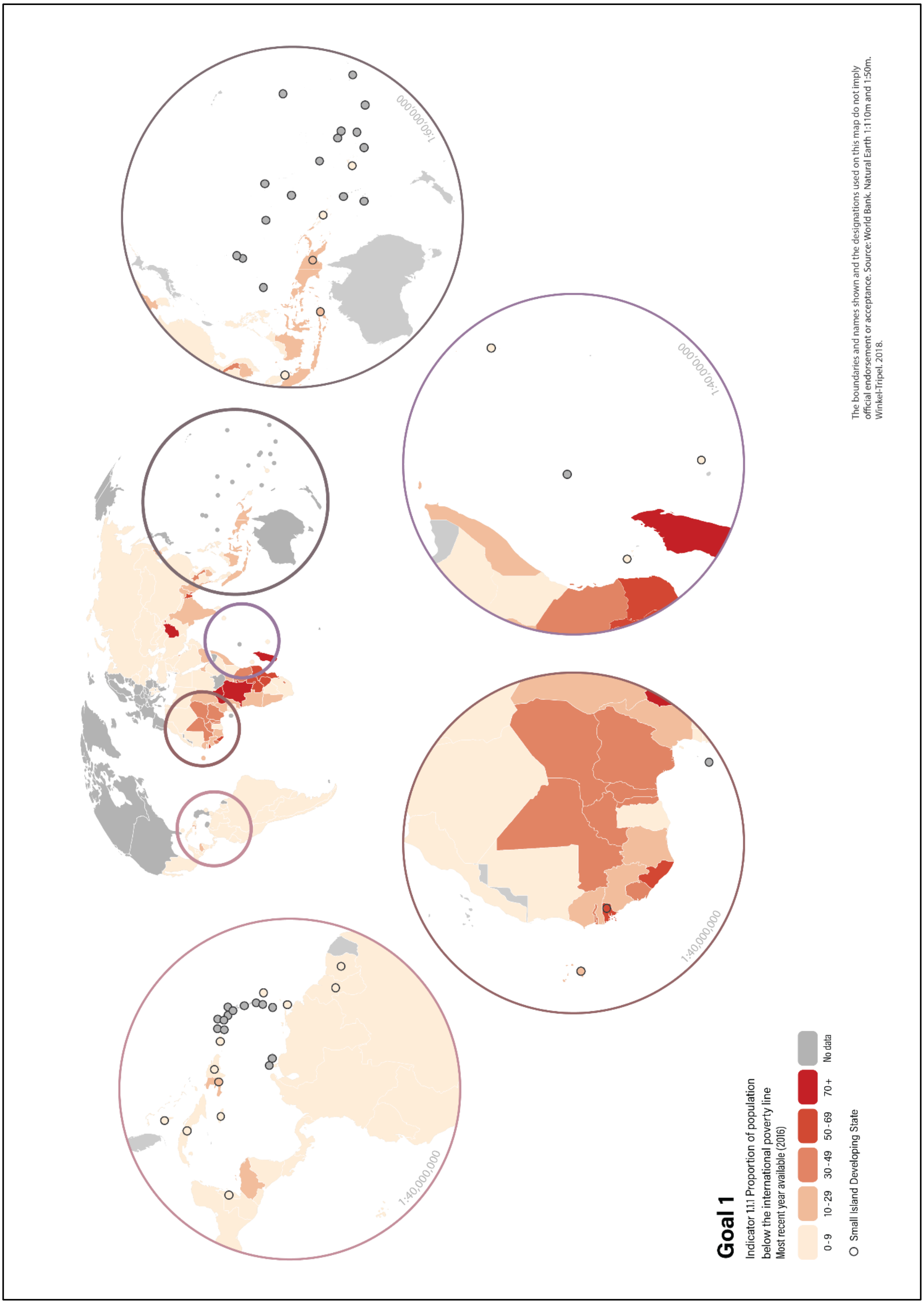
Goal 1
Indicator 1.1.1 Proportion of population below the international poverty line
Most recent year available (2016)
0-9
10-29
30-49
50-69
70+
No data
Small Island Developing State
The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance. Source: World Bank. Natural Earth 1:50m. Winkel-Tripel. 2018.

## Map B



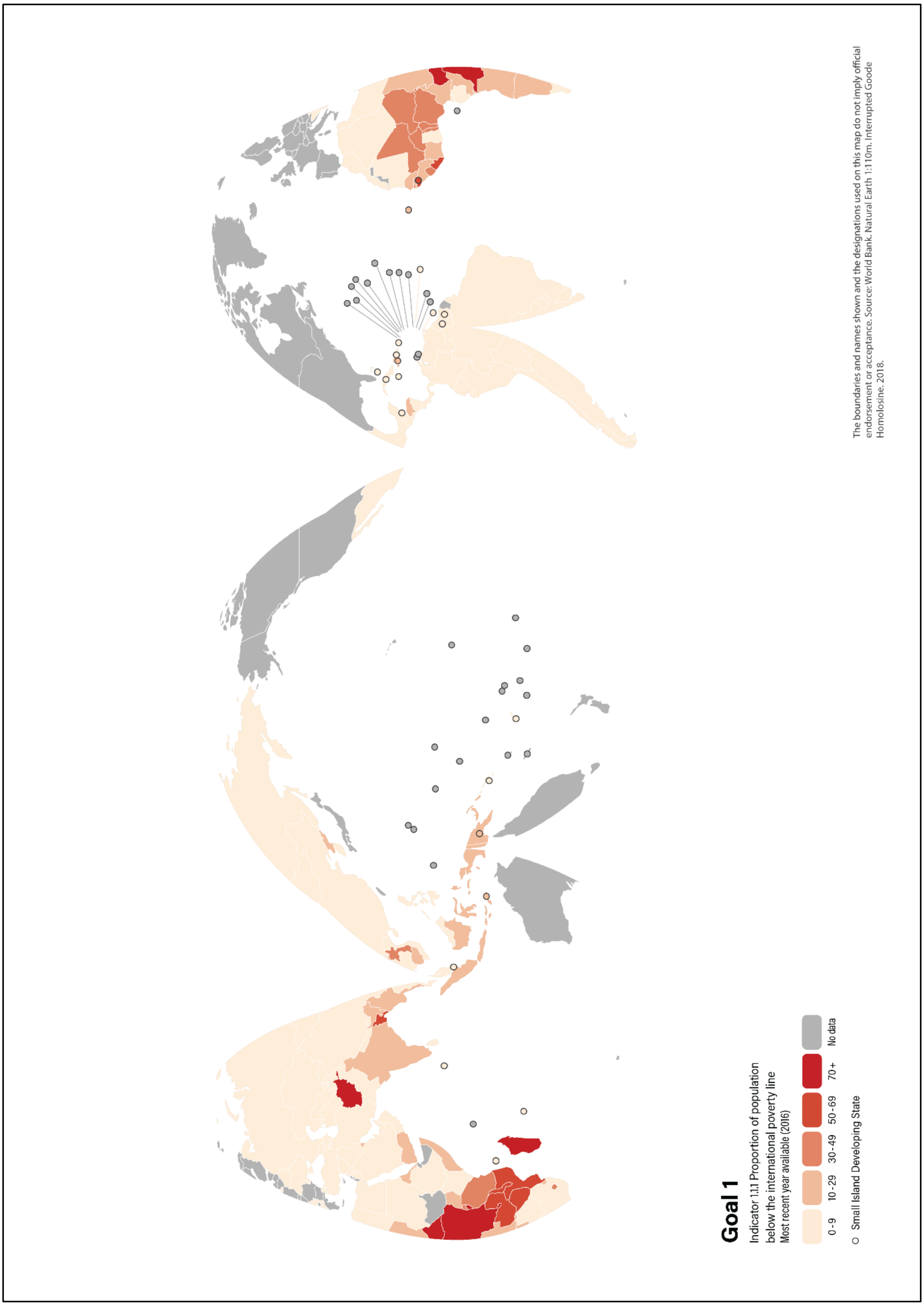
1:60,000,000
1:40,000,000
1:40,000,000
1:40,000,000
Goal 1
Indicator 1.1.1 Proportion of population below the international poverty line
Most recent year available (2016)
0-9
10-29
30-49
50-69
70+
No data
Small Island Developing State
The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance. Source: World Bank. Natural Earth 1:110m and 1:50m. Winkel-Tripel. 2018.

## Map C



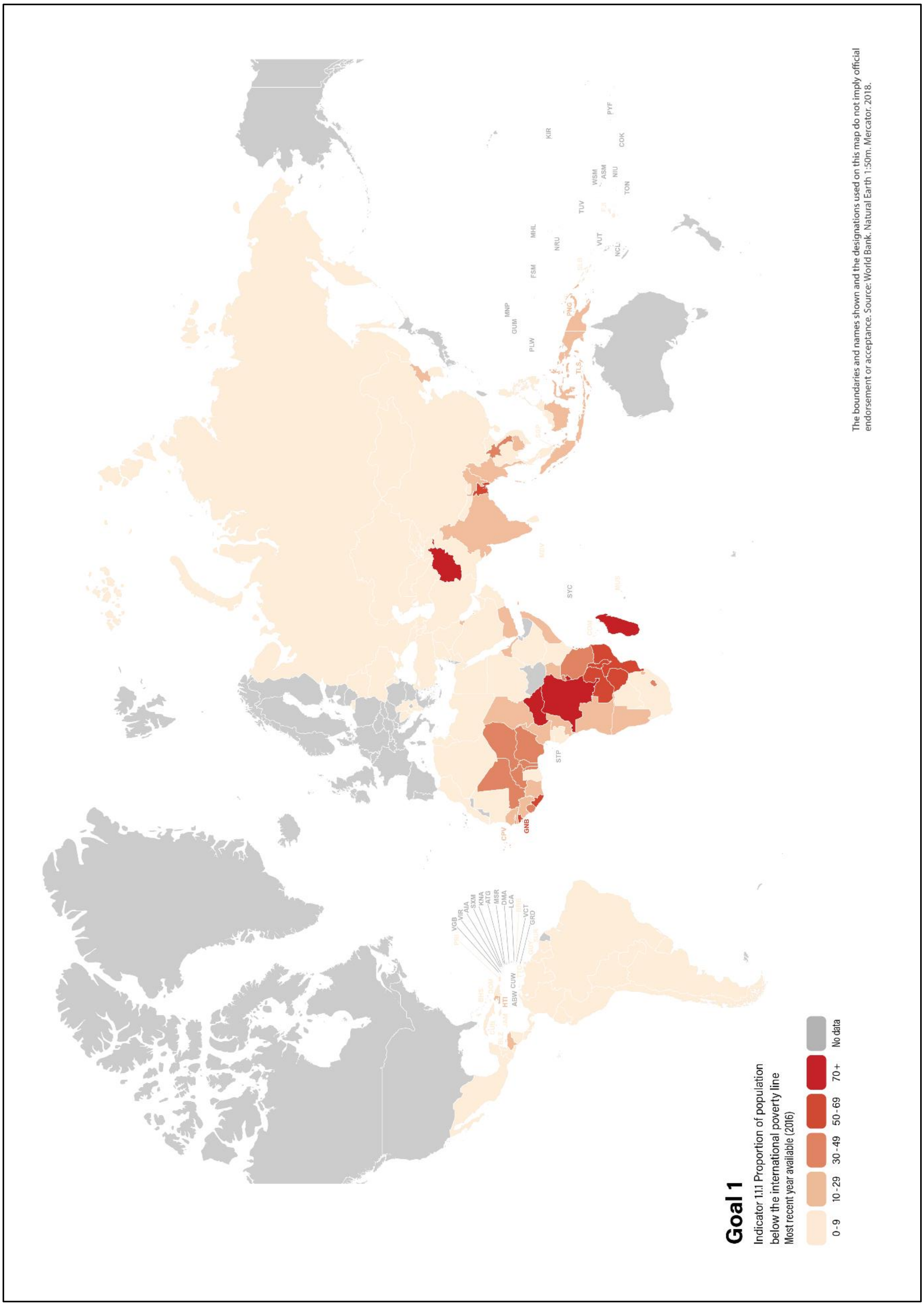
1:60,000,000
1:40,000,000
1:40,000,000
1:40,000,000
Goal 1
Indicator 1.1.1 Proportion of population below the international poverty line
Most recent year available (2016)
0 - 9
10 - 29
30 - 49
50 - 69
70 +
No data
Small Island Developing State
The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance. Source: World Bank. Natural Earth 1:110m and 1:50m. Winkel-Tripel. 2018.

## Map D



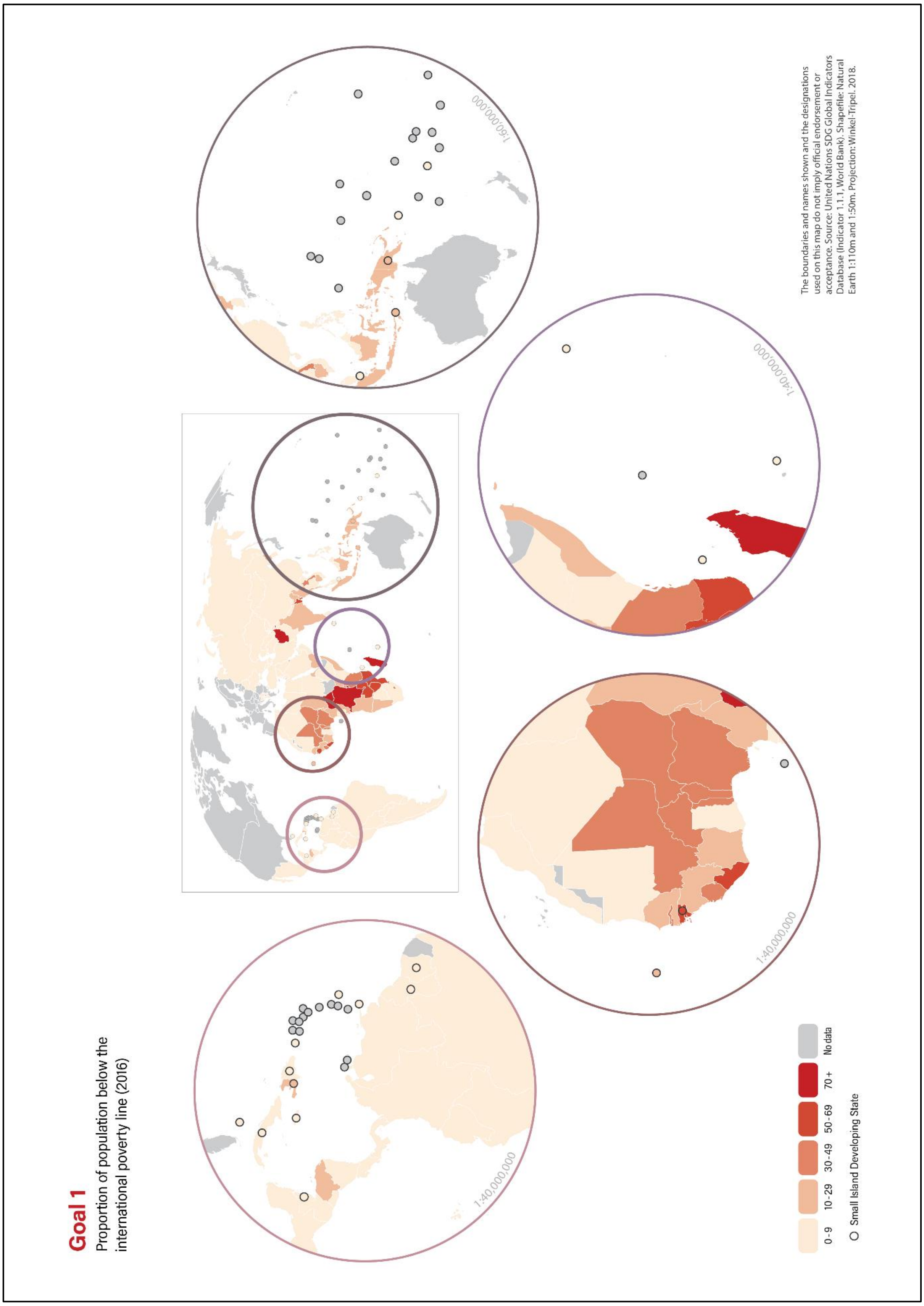
Goal 1
Indicator 1.1.1 Proportion of population below the international poverty line
Most recent year available (2016)
0-9
10-29
30-49
50-69
70+
No data
Small Island Developing State
The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance. Source: World Bank. Natural Earth 1:110m. Interrupted Goode Homolosine. 2018.

## Map E

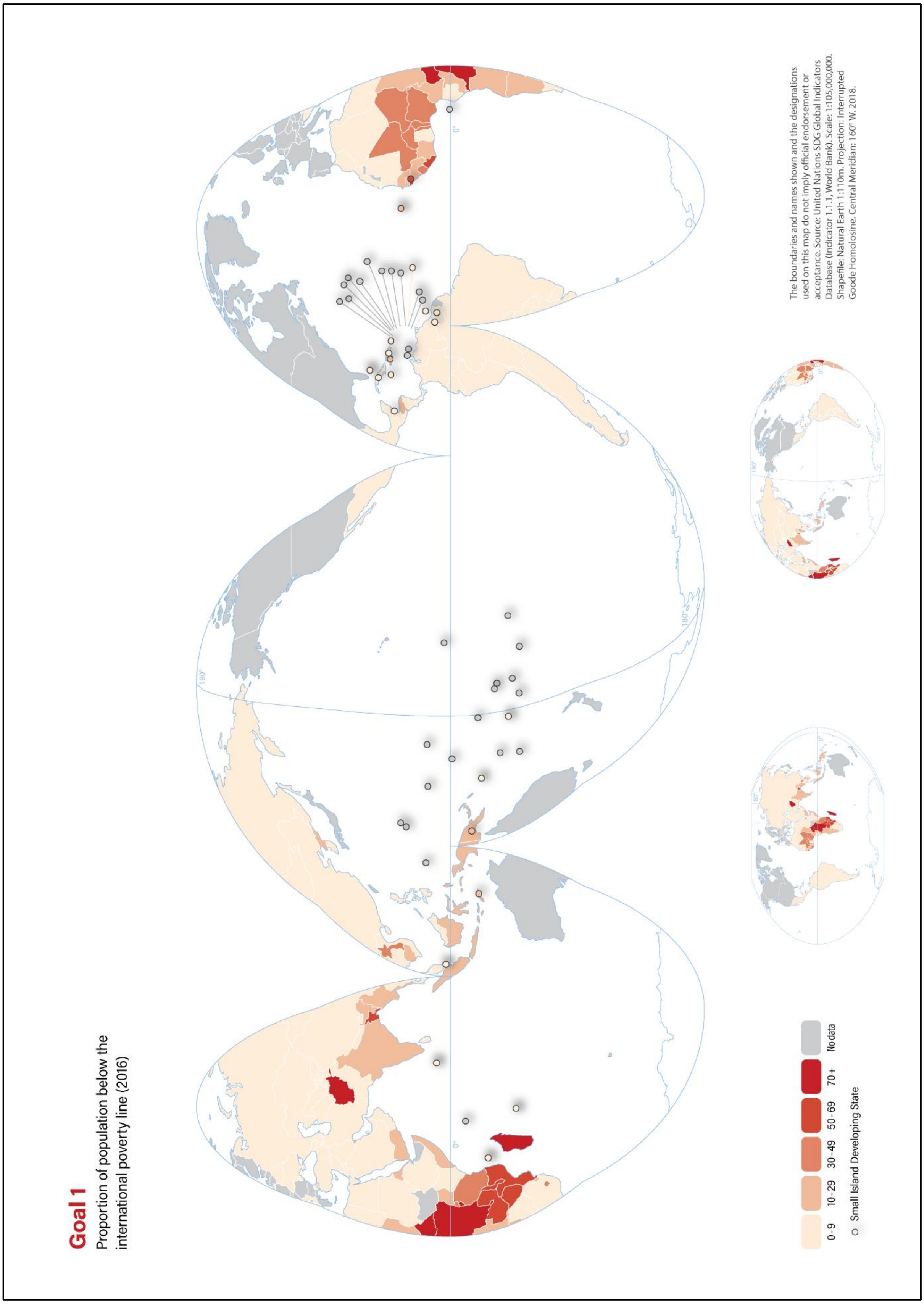

Goal 1
Indicator 1.1.1 Proportion of population below the international poverty line
Most recent year available (2016)
0-9
10-29
30-49
50-69
70+
No data
The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance. Source: World Bank. Natural Earth 1:50m. Mercator. 2018.

**Appendix H – Revised 1 maps (next page)**

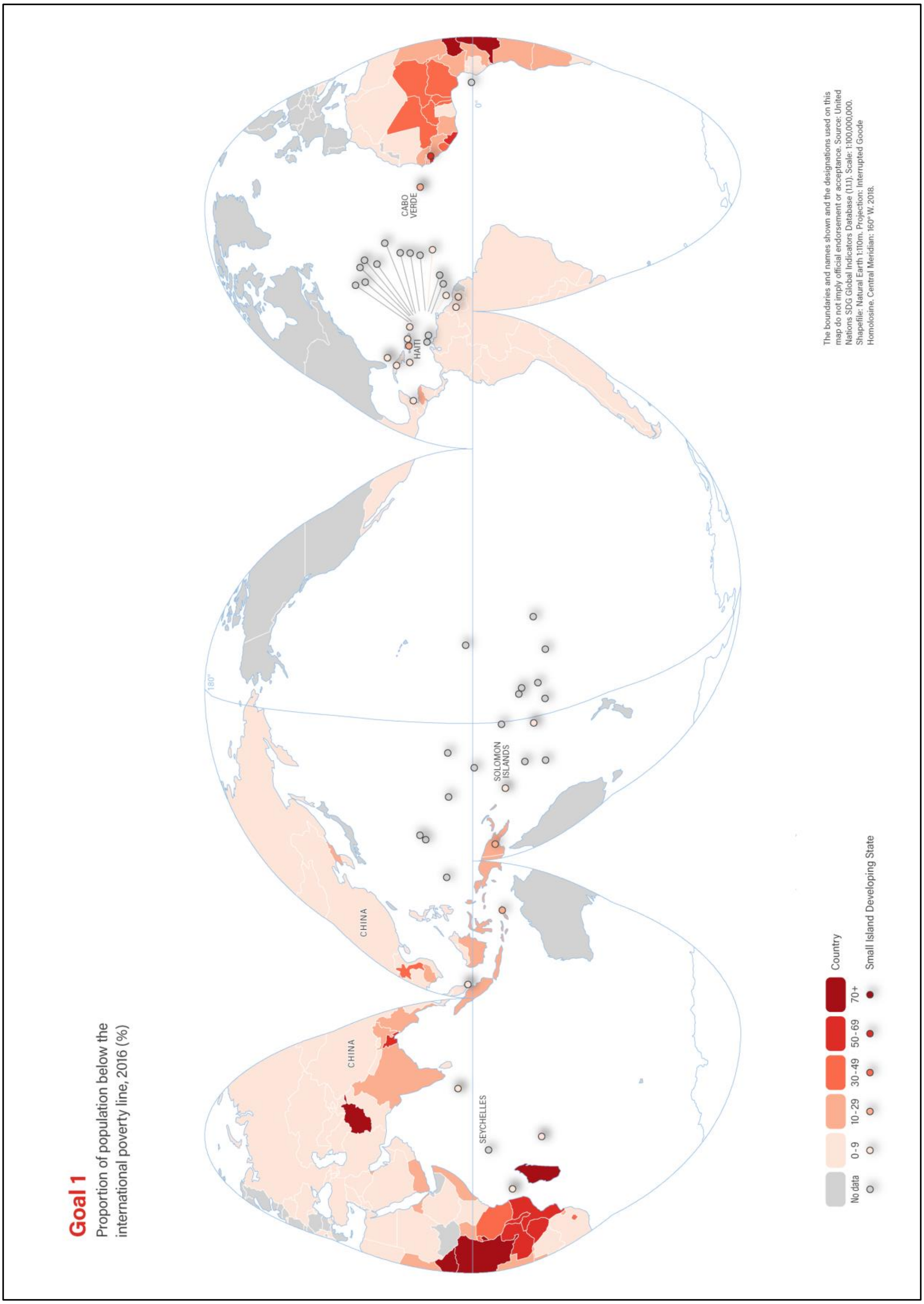
## Map C – Revised 1



**Map D – Revised 1**



**Appendix I – Map D – Revised 2**



## Appendix J – Online Survey results

Q1. What is poverty rate in Cabo Verde?

| Answer Choices | Response Percent | Responses |
|---|---|---|
| 0-9% | 0.0% | 0 |
| 10-29% | 79.55% | 70 |
| 30-49% | 14.77% | 13 |
| 50-69% | 0.0% | 0 |
| 70 percent or more | 1.14% | 1 |
| Unavailable (no data) | 2.27% | 2 |
| Not sure | 2.27% | 2 |
| | Answered | 88 |
| | Skipped | 6 |

Q2. What is the poverty rate in the Seychelles?

| Answer Choices | Response Percent | Responses |
|---|---|---|
| 0-9% | 11.63% | 10 |
| 10-29% | 5.81% | 5 |
| 30-49% | 0.0% | 0 |
| 50-69% | 0.0% | 0 |
| 70 percent or more | 0.0% | 0 |
| Unavailable (no data) | 80.23% | 69 |
| Not sure | 2.33% | 2 |
| | Answered | 86 |
| | Skipped | 8 |

Q3. What is the poverty rate in China?

| Answer Choices | Response Percent | Responses |
|---|---|---|
| 0-9% | 86.05% | 74 |
| 10-29% | 10.47% | 9 |
| 30-49% | 0.0% | 0 |
| 50-69% | 0.0% | 0 |
| 70 percent or more | 2.33% | 2 |
| Unavailable (no data) | 0.0% | 0 |
| Not sure | 1.16% | 1 |
| | Answered | 86 |
| | Skipped | 8 |

Q4. This map made it ____________ to answer these questions.

| Answer Choices | Response Percent | Responses |
|---|---|---|
| Very easy | 14.94% | 13 |
| Easy | 47.13% | 41 |
| Neither easy nor difficult | 18.39% | 16 |
| Difficult | 17.24% | 15 |
| Very difficult | 2.3% | 2 |
| | Answered | 87 |
| | Skipped | 7 |

Q5. Which Small Island Developing State has a higher poverty rate, the Solomon Islands or Haiti?

| Answer Choices | Response Percent | Responses |
|---|---|---|
| Solomon Islands | 3.57% | 3 |
| Haiti | 96.43% | 81 |
| | Answered | 84 |
| | Skipped | 10 |

Q6. Which region of the world has countries with higher poverty rates than the Small Island Developing States in the Caribbean?

| Answer Choices | Response Percent | Responses |
|---|---|---|
| South America | 7.14% | 6 |
| Central Africa | 92.86% | 78 |
| North America | 0.0% | 0 |
| | Answered | 84 |
| | Skipped | 10 |

Q7. This map made it ____________ to answer these questions.

| Answer Choices | Response Percent | Responses |
|---|---|---|
| Very easy | 12.94% | 11 |
| Easy | 34.12% | 29 |
| Neither easy nor difficult | 31.76% | 27 |
| Difficult | 20.0% | 17 |
| Very difficult | 1.18% | 1 |
| | Answered | 85 |
| | Skipped | 9 |

Q8. What is the approximate percentage of Small Island Developing States without data in the Pacific Ocean?

| Answer Choices | Response Percent | Responses |
|---|---|---|
| 100% | 17.72% | 14 |
| 75% | 64.56% | 51 |
| 50% | 2.53% | 2 |
| 25% | 6.33% | 5 |
| 0% | 0.0% | 0 |
| Not sure | 8.86% | 7 |
| | Answered | 79 |
| | Skipped | 15 |

Q9. What is the approximate percentage of Small Island Developing States without data world-wide?

| Answer Choices | Response Percent | Responses |
|---|---|---|
| 100% | 3.8% | 3 |
| 75% | 68.35% | 54 |
| 50% | 12.66% | 10 |
| 25% | 6.33% | 5 |
| 0% | 0.0% | 0 |
| Not sure | 8.86% | 7 |
| | Answered | 79 |
| | Skipped | 15 |

Q10. What is the approximate percentage of all countries without data world-wide?

| Answer Choices | Response Percent | Responses |
|---|---|---|
| 100% | 0.0% | 0 |
| 75% | 10.13% | 8 |
| 50% | 22.78% | 18 |
| 25% | 50.63% | 40 |
| 0% | 2.53% | 2 |
| Not sure | 13.92% | 11 |
| | Answered | 79 |
| | Skipped | 15 |

Q11. This map made it _____________ to answer these questions.

| Answer Choices | Response Percent | Responses |
|---|---|---|
| Very easy | 1.25% | 1 |
| Easy | 21.25% | 17 |
| Neither easy nor difficult | 36.25% | 29 |
| Difficult | 28.75% | 23 |
| Very difficult | 12.5% | 10 |
| | Answered | 80 |
| | Skipped | 14 |

Q12. The design of this map is appropriate to show available and unavailable data for Small Island Developing States.

| Answer Choices | Response Percent | Responses |
|---|---|---|
| Strongly agree | 12.66% | 10 |
| Agree | 54.43% | 43 |
| Neither agree nor disagree | 7.59% | 6 |
| Disagree | 20.25% | 16 |
| Strongly disagree | 5.06% | 4 |
| | Answered | 79 |
| | Skipped | 15 |

Q13. The design of this map was appropriate to show available and unavailable data for all countries.

| Answer Choices | Response Percent | Responses |
|---|---|---|
| Strongly agree | 5.13% | 4 |
| Agree | 39.74% | 31 |
| Neither agree nor disagree | 17.95% | 14 |
| Disagree | 30.77% | 24 |
| Strongly disagree | 6.41% | 5 |
| | Answered | 78 |
| | Skipped | 16 |

Q14. It would be easier to identify Small Island Developing States with unavailable data if the islands without data were represented by a square rather than a circle.

| Answer Choices | Response Percent | Responses |
|---|---|---|
| Strongly agree | 5.06% | 4 |
| Agree | 37.97% | 30 |
| Neither agree nor disagree | 20.25% | 16 |
| Disagree | 34.18% | 27 |
| Strongly disagree | 2.53% | 2 |
| | Answered | 79 |
| | Skipped | 15 |