MAPPING FOR A SUSTAINABLE WORLD

United Nations

ICA ACI

Mapping for a Sustainable World

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Kraak MJ, RE Roth, B Ricker, A Kagawa, and G Le Sourd. 2020.
***Mapping for a Sustainable World*. The United Nations: New York, NY (USA).**

Foreword

The year 2020 started the "Decade of Action" for attaining the Sustainable Development Goals as set out in the 2030 Agenda—our shared vision to end poverty, rescue the planet, and build a peaceful world.

The United Nations Secretary-General called for making better use of data so that everyone, everywhere uses data for insight, impact, and integrity. Data action must bring value to people and the planet.

Cartography enables analysis of large amounts of data and visualization of the result for better understanding. Cartography often is referred as a science and an art form. Art is the conscious creation of something beautiful with emotional power, often in visual form. This power must be harnessed to raise awareness and understanding on priority agendas for a better world, and to provide science and data for action and decision-making in moments that matter most.

In partnership with the International Cartographic Association (ICA), *Mapping for a Sustainable World* brings to you best practices and methods in geospatial data and cartography to help unveil challenges and achievements towards the Sustainable Development Goals.

—Kyoung-Soo Eom,
Chief of the
Geospatial Information Section,
United Nations

The United Nations fostered a needed challenge to countries of the world to leave no one behind. A plan for attainment was set for the year 2030 through the Sustainable Development Goals. In order to achieve the goals, targets, and indicators, each country needs large volumes of data to determine their baseline and similar data collected at an on-going basis. These data provide comparative findings useful for future planning.

The variable types of data required for specific SDGs and the volume of data points needed at the appropriate levels of geography can be overwhelming. Looking at the numbers and trying to absorb their meaning and implications is an onerous task. Using maps, mapping technology, and the skills of cartographers helps in synthesizing and visualizing complex data. Maps make it possible to see trends and make comparisons between different areas and over different time periods. Mapping helps in better understanding the stories and implications of each Sustainable Development Goal for a country.

This collaboration on *Mapping for a Sustainable World* between the ICA and United Nations is an example of how two international organizations working together yields benefits and a path forward toward the common goal of leaving no one behind.

—Tim Trainor,
President,
International Cartographic Association

The boundaries and names shown and the designations used in this book do not imply official endorsement or acceptance by the United Nations.

Contributions to this Book

The book has an editorial team comprising writers from the International Cartographic Association (ICA) and the Geospatial Information Section of the United Nations (UN). Editorial members include Menno-Jan Kraak (ICA), Robert E. Roth (ICA), Britta Ricker (ICA), Ayako Kagawa (UN), and Guillaume Le Sourd (UN).

The editorial team drafted and collectively edited text for most sections and created preliminary illustrations. Several sections draw from the ICA Poster Project (https://icaci.org/maps-and-sustainable-development-goals/) completed by members from the ICA Commissions and Working Groups. Yuri Engelhardt (University of Twente) contributed to the sections on diagrams. Mina Lee (UN) edited the figures and Donna Cattano (UN) copyedited the text.

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Funds from the International Cartographic Association's International Year of the Map Project have made a printed version of the book possible for free distribution to UN Member States and participating ICA Commissions.

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Introduction

In 2015, the United Nations identified 17 ***Sustainable Development Goals*** (henceforth ***SDGs***) in an effort to address, collectively, the most pressing problems facing our world. The SDGs relate to broad social, economic, and environmental challenges, and provide a framework for shared action. Each of the 17 SDGs has a set of targets and indicators to assist countries towards meeting the goal. To achieve the SDGs, governments and people need to understand each challenge and monitor progress towards alleviating it.

Well-designed maps and diagrams support this process because they effectively reveal spatio-temporal patterns, such as global population growth, socioeconomic disparities, and climate change. Maps reduce complexity and reveal spatial patterns that might otherwise go unnoticed. As such, they help us to better understand the relationship between humans and their environment as well as enable us to monitor SDG indicators and communicate their uneven global footprints. These visualizations support decision-making by local and national authorities as well as promote public awareness of global issues to encourage these authorities to act.

The design of maps and diagrams is an intentional process, and the same subject can be mapped or charted in a number of different, equally appropriate ways. However, some design decisions are suboptimal for particular mapping contexts, resulting in flawed or even misleading maps and diagrams. Problems also regularly originate from improper data handling, distracting symbols and text, confusing map elements, and the (mis)use of software defaults.

Cartography describes the art, science, and technology of making and using maps. Drawing from cartography, this book offers guidelines for mapping geographic datasets related to the SDGs by introducing basic principles of map design and use, discussing established best practices and conventions, and explaining how different mapping techniques support understanding of the SDGs. As such, the following sections offer recommendations to avoid common pitfalls in cartographic design rather than enforce hard-and-fast rules required in all mapping contexts. The book is of interest to those who want to make and use "SDG maps" that help create a sustainable world.

—Menno-Jan Kraak,
Robert E. Roth, and Britta Ricker,
International Cartographic Association

—Ayako Kagawa,
and Guillaume Le Sourd,
Geospatial Information Section,
United Nations

Structure & Table of Contents

The book comprises four sections. Section 1 introduces the SDGs and their relation to geospatial data, describing SDG indicators and data transformations for mapping. Section 2 describes foundational design decisions in the cartographic workflow including projections, scale, generalization, symbolization, typography, and visual hierarchy among others. Section 3 introduces common map types (e.g., choropleth maps, proportional symbol maps, dasymetric maps, bivariate maps, cartograms) and diagrams (e.g., bar graphs, scatterplots, timelines) for representing the SDG indicators. Finally, Section 4 discusses considerations for map use environments such as audiences, user interfaces and interaction operators, mobile and web media, storytelling versus exploration, and open access.

SUSTAINABLE DEVELOPMENT GOALS

1 NO POVERTY

2 ZERO HUNGER

3 GOOD HEALTH AND WELL-BEING

4 QUALITY EDUCATION

5 GENDER EQUALITY

6 CLEAN WATER AND SANITATION

7 AFFORDABLE AND CLEAN ENERGY

8 DECENT WORK AND ECONOMIC GROWTH

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

10 REDUCED INEQUALITIES

11 SUSTAINABLE CITIES AND COMMUNITIES

12 RESPONSIBLE CONSUMPTION AND PRODUCTION

13 CLIMATE ACTION

14 LIFE BELOW WATER

15 LIFE ON LAND

16 PEACE, JUSTICE AND STRONG INSTITUTIONS

17 PARTNERSHIPS FOR THE GOALS

SUSTAINABLE DEVELOPMENT GOALS

SECTION 1: SDGs & GEOSPATIAL DATA

1.1 The Sustainable Development Goals

Figure 1.1-1: The SDGs. The Sustainable Development Goals are a collective global effort to address 17 of the most pressing problems facing our world.

The 2030 Agenda for Sustainable Development, referred to as the ***Sustainable Development Goals***, was adopted in 2015 by the Member States as the overarching blueprint to achieve a better and more sustainable future for all and to address global challenges (**Figure 1.1-1**).

World leaders use the ***global indicator framework*** to report their SDGs at global, regional, national, and local levels. The 17 ***goals*** address the most pressing problems facing our world. Each goal is divided into more specific ***targets***, 169 in total, that prescribe real and actionable outcomes for a sustainable world. Finally, 231 unique ***indicators***, as of April 2020, are used to measure and monitor progress towards each target, to inform policy, and to ensure accountability of all stakeholders (see Section 1.6). Reliable, timely, accessible, and disaggregated data, including geospatial data and Earth observations, is essential for the global indicator framework to be insightful and impactful.

The ***Inter-Agency and Expert Group on SDG Indicators*** (***IAEG-SDGs***) is responsible for uniting the global community to develop and implement the global indicator framework. The IAEG-SDGs established the ***Working Group on Geospatial Information*** (***WG-GI***) to address the importance and relevance of geospatial dimensions of the SDGs.

The WG-GI guides the IAEG-SDGs on how geospatial data can contribute to SDG indicator development and improve national and sub-national reporting.

Maps effectively communicate SDG challenges and successes to improve global awareness. Interactive, online, and mobile maps can be used to collect, process, manage, analyze, visualize, and disseminate the SDG indicators. Accordingly, cartographers play an important role in providing insightful maps and geospatial data to policy and decision-makers that measure and monitor SDG-related initiatives. Furthermore, cartographers have an opportunity to illustrate the extensive value of maps and geospatial data as exploratory, analytical, synthesis, and presentation tools through the SDG initiative.

- **SDG website:** https://www.un.org/sustainabledevelopment/sustainable-development-goals/
- **Global SDG Indicators Database:** https://unstats.un.org/sdgs/indicators/database/
- **SDG regional groupings (used in this book):** https://unstats.un.org/sdgs/indicators/regional-groups
- **SDG tier classification:** https://unstats.un.org/sdgs/iaeg-sdgs/tier-classification/
- **SDG indicator list:** https://unstats.un.org/sdgs/indicators/indicators-list/
- **Inter-Agency and Expert Group on SDG Indicators (IAEG-SDGs):** https://unstats.un.org/sdgs/iaeg-sdgs/
- **Working Group on Geospatial Information (WG-GI):** http://ggim.un.org/UNGGIM-wg6/

1.2 Geospatial Data

Geospatial data describes aspects of the natural and built environments and has three components (**Figure 1.2-1**): location, attribute(s), and time.

Location is about *where*, with the location of a mapped phenomenon often indicated by an address or coordinate (see Section 1.3). The United Nations Headquarters address is 405 East 42nd Street, New York, NY, 10017, USA, for example. ***Geographic coordinates*** are based on the Earth's geometry and measured in degrees ***latitude*** (parallels north–south) and ***longitude*** (meridians east–west). The United Nations Headquarters geographic coordinates are 40°44'34.79"N and 73°58'2.99"W. A ***graticule*** of latitude/longitude intervals can be projected in the map as an orientation of north.

Attribute is about *what* or *who* is represented (see Section 1.4). Attributes describe qualitative or quantitative characteristics of the mapped phenomenon (**Figure 1.2-2**). An example of a qualitative attribute is the land use around the United Nations Headquarters. This nominal map depicts each land-use category with a different colour hue (see Section 3.2). An example of a quantitative attribute is the building heights of the same area. This proportional symbol map depicts the heights of the buildings by symbols that vary in size (see Section 3.4).

Time is about *when* an event occurred at the specified location or *when* the data was collected (see Section 1.5). Depending on data availability, the temporal component of geospatial data (sometimes combined as "spatio-temporal" data) can depict geographic changes, trends, and underlying processes. For example, adjacent maps of spatiotemporal data can be used to compare the surrounding context of the United Nations Headquarters in the year 1836 versus today (**Figure 1.2-3**).

United Nations data for the SDGs is inherently geospatial. SDG datasets are reported for a country or region (location), contain multiple indicators for each goal (attributes), and are gathered across multiple years (time) to support monitoring of progress towards the SDGs.

The datasets mapped in this book are from the Global SDG Indicators Database (https://unstats.un.org/sdgs/indicators/database/). These data are regularly updated and freely available for download and use (**Figure 1.2-4**).

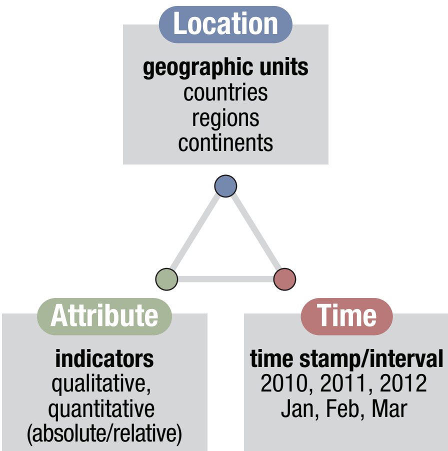


Figure 1.2-1: Components of geospatial data: location, attributes, and time.

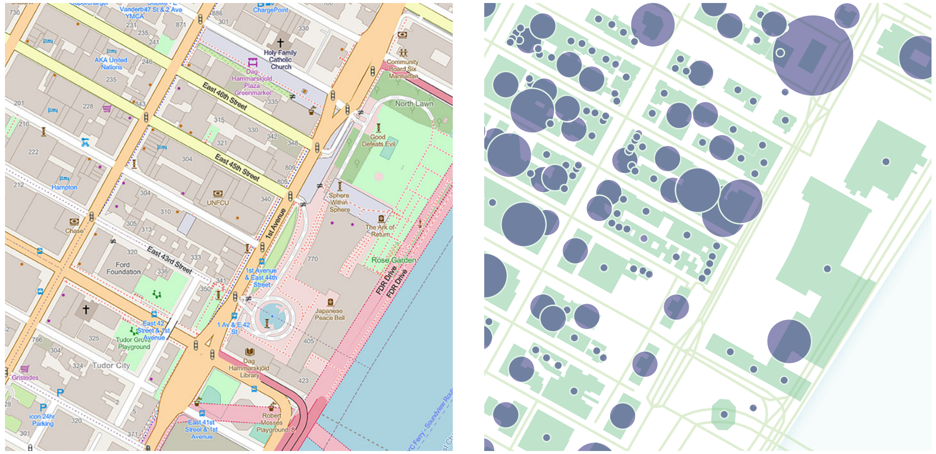


Figure 1.2-2: Attributes. **Left:** A qualitative attribute: land use around the United Nations Headquarters (Source: OpenStreetMap). **Right:** A quantitative attribute: building heights around the United Nations Headquarters.

Figure 1.2-3: Time. **Left:** The area around the United Nations Headquarters in 1836 (Source: Joseph Colton, Smithsonian Magazine). **Right:** The same area today (Source: Google Maps).

Attributes					Location				Time					
Goal	Target	Indicator	SeriesCode	SeriesDescription	GeoArea	GeoAreaName	Location	Units	2000	2001	2002	2003	…	2017
6	6.1	6.1.1	SH_H2O_SAFE	Proportion of popu	112	Belarus	ALLAREA	PERCE	80.62	80.81	80.99	81.17	…	94.52
6	6.1	6.1.1	SH_H2O_SAFE	Proportion of popu	100	Bulgaria	ALLAREA	PERCE	96.84	96.84	96.84	96.81	…	96.95
6	6.1	6.1.1	SH_H2O_SAFE	Proportion of popu	203	Czechia	ALLAREA	PERCE	96.32	96.32	96.44	96.55	…	97.88
6	6.1	6.1.1	SH_H2O_SAFE	Proportion of popu	348	Hungary	ALLAREA	PERCE	50.51	50.51	50.51	50.51	…	89.57
6	6.1	6.1.1	SH_H2O_SAFE	Proportion of popu	616	Poland	ALLAREA	PERCE					…	99.16
6	6.1	6.1.1	SH_H2O_SAFE	Proportion of popu	498	Republic of Mold	ALLAREA	PERCE	40.42	42.32	44.27	46.26	…	72.88
6	6.1	6.1.1	SH_H2O_SAFE	Proportion of popu	642	Romania	ALLAREA	PERCE	81.65	81.61	81.59	81.63	…	81.92

Figure 1.2-4 (Opposite side): An example data download from the Global SDG Indicators Database. Indicator 6.1.1 (2015) on the proportion of population using safe drinking water is organized by components of geospatial data: location (blue), attributes (green), and time (red).

1.3 Location Data: Representing the World

Location describes the where of geospatial data. Location is a complex topic for several reasons.

First, location data cvan be both ***relative*** (e.g., directions from an arbitrary landmark or other location) or ***absolute*** (e.g., coordinates in a predefined reference system), with absolute coordinates often misaligning due to different (0,0) origins. Accordingly, global location data compilation often requires painstaking georeferencing and conversion across coordinate systems and data formats before mapping.

Second, in a ***vector data model***, locations are described as nodes comprising pairwise (X,Y) coordinates and arcs connecting nodes. Vector data results in ***points*** (nodes only), ***lines*** (nodes and arcs), ***polygons*** (enclosed nodes and arcs), and ***volumes*** (3D objects) (see Section 2.8). The appropriate dimension for capturing and visualizing location data depends on the map purpose (see Section 2.1), cartographic scale (see Section 2.6), and generalization (see Section 2.7).

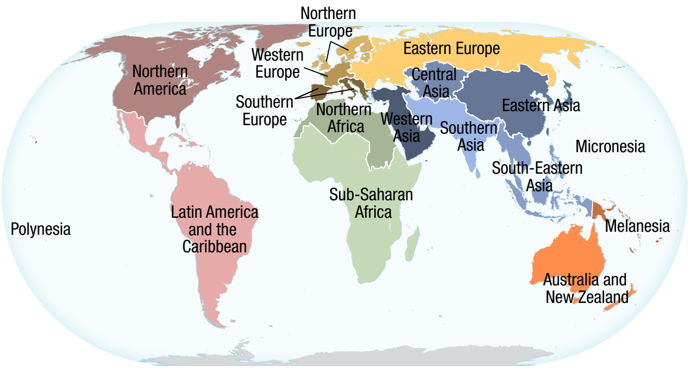


Figure 1.3-1: The M49 regions and sub-regions. M49 regions (Africa, Americas, Asia, Europe and Oceania) are differentiated by colour hue. Sub-regions are given variable tones within the associated regional hue and marked by white boundaries and labels.

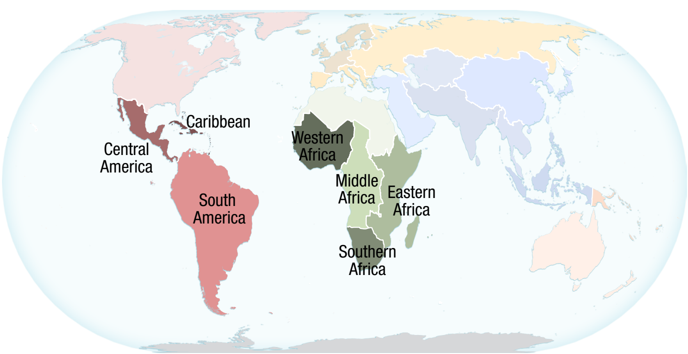


Figure 1.3-2: The M49 intermediate regions. Additional M49 intermediate regions used for greater specificity within some sub-regions. Colour hue again is used for the broader M49 regions for comparison to Figure 1.3-1.

Finally, "(geo)spatial" is a "special" case in data science due to ***spatial autocorrelation***: near locations are more likely to be similar in both attribute and time than distant locations. Thus, common techniques for data capture and statistical analysis do not apply to location data given their topological relationships.

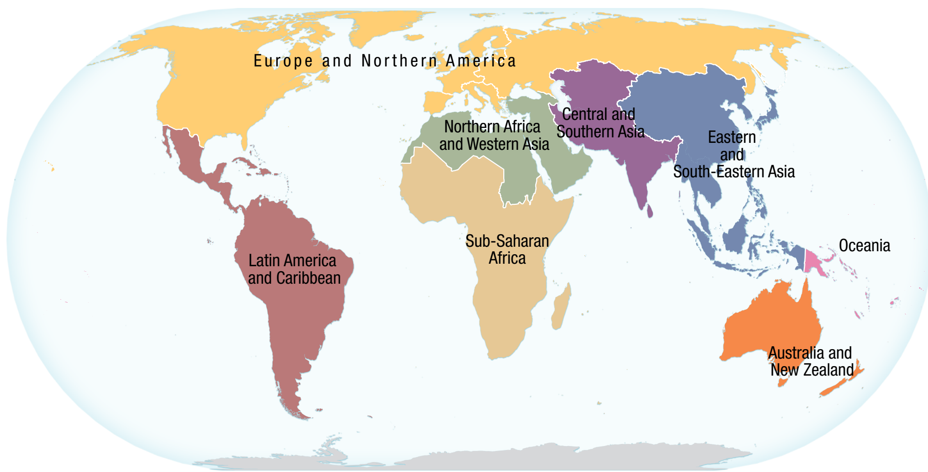
The SDG regional groupings to monitor SDG progress are based on the geographic regions defined under the ***Standard Country or Area Codes for Statistical Use***, also known as the ***M49 standard***. Geographic regions, areas, and countries are given three-digit numerical codes used for statistical processing by the Statistics Division of the United Nations (***M49 codes***). Countries and areas also have three-digit alphabetical codes assigned by the International Organization for Standardization (ISO).

M49 ***regions*** are major continental regions that are divided into ***sub-regions*** (Figure 1.3-1), with some sub-regions further divided into ***intermediate regions*** (Figure 1.3-2). These geographic regions are drawn to obtain greater homogeneity in sizes of population, demographic circumstances, and accuracy of demographic statistics. Finally, a ***country*** is a sovereign political administrative unit acknowledged in the M49 standard.

For the purpose of presentation, the SDG regional groupings combine specific M49 geographic regions and sub-regions (Figure 1.3-3).

In addition, specific country group lists are also defined for Least Developed Countries (LDC), Landlocked Developing Countries (LLDC), and Small Island Developing States (SIDS). Lists for SDG regional groupings and specific country groups are detailed at: https://unstats.un.org/sdgs/indicators/regional-groups.

Figure 1.3-3: The SDG regional groupings. The SDG regional groupings used to compile and report indicator data.



1.4 Attribute Data: SDG Indicators & Levels of Measurement

An attribute describes the *what* or *who* of geospatial data. Attribute data that is tied to location comes in two forms. An ***individual-level attribute*** describes unique conditions or qualities of a specific place (e.g., the tax rate applied consistently for an entire administrative unit).

In contrast, an ***enumerated attribute*** aggregates or counts individual data within a predefined space (e.g., the population within a country). Most of the SDG indicators are enumerated, making the M49 polygonal boundaries—or ***enumeration units***—critical to how SDG indicators are collected and subsequently how their geospatial patterns appear when mapped (see Section 1.8).

Attributes are collected on one of four data scales or ***levels of measurement*** (Figure 1.4-1).

Ratio-level data is quantitative and the values are counted or calculated from a meaningful zero value. An example is the number of inhabitants for each country. Most enumerated attributes are reported at a ratio level, with a fixed zero indicating the baseline count of zero.

Interval-level data also is quantitative, but the zero value is arbitrary and, thus, limits estimation of relative magnitudes. An example is temperature measured in Celsius: zero represents the point at which water freezes and not the total absence of heat (i.e., absolute zero). No indicators are reported at an interval level of measurement. Interval and ratio data together are described as ***numerical*** or ***quantitative*** (see Section 1.2).

Ordinal-level data describes non-numerical ranking, such as first-to-last, high-to-low, or good-to-bad. Ratio or interval data may be converted to ordinal to simplify the map legend, but ordinal data cannot be converted to numerical data.

Finally, ***nominal-level*** data refers to unranked categories, such as the M49 delineation of countries into different geographic regions, sub-regions, and intermediate regions (see Section 1.3). Nominal data also is described as ***qualitative*** (see Section 1.2).

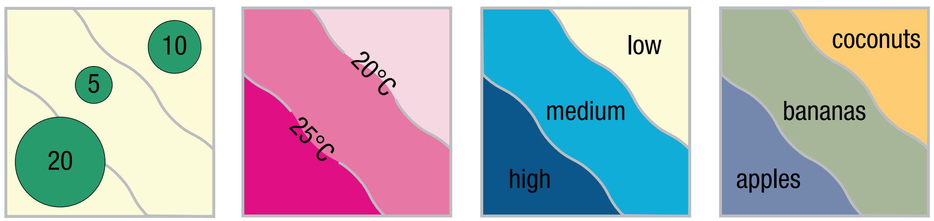


Figure 1.4–1: Attribute levels of measurement and associated example symbolization. **Left to right**: Ratio data mapped with a proportional symbol map (see Section 3.4), interval data mapped with an isoline map (see Section 3.1), ordinal data mapped with a choropleth map (see Section 3.3), and nominal data mapped with a nominal map (see Section 3.2).

The attribute level of measurement guides appropriate symbol selection in maps (Figure 1.4-2).

As with location data, ratio-level attribute data can be both absolute and relative. An ***absolute*** attribute is measured or counted and reported without consideration of other attributes. A ***relative*** attribute is normalized based on one, two, or multiple other values. Two values belonging to the same attribute result in a ***proportion*** (a percentage), two values belonging to two different attributes lead to a ***rate*** (e.g., a count of something per population), and multiple values belonging to multiple attributes result in an ***index*** (based on formula).

Ratio-level SDG indicators include both absolute and relative attributes. Absolute attributes often are described as "raw" data and need to be converted to relative attributes through ***normalization*** (see Section 1.7).

Many enumerated SDG indicators already are reported as proportions or rates related to population. However, population and other enumerated attributes rarely are evenly distributed within the enumeration units. Normalizing ratio-level data is useful both to mask privacy of individual-level data and to ensure visual comparability of enumerated data across enumeration units of varying arrangement, shape, and size.

Level of Measurement	Absolute/ Relative	Attributes	Mappable Values		Example
ratio	absolute (one value)	one attribute	absolute value		count X
	relative (calculated using two or more attributes)	one attribute	proportion	proportion of total population	% of total population
				other proportion	% of X, other than population
		two attributes	rate	rate per capita	count X per capita/ population
				change rate (per time unit)	% change or count X per time
				other rate	X per Y, other than population or time
		many attributes	index (calculated)		formula
interval			interval value		*not used for SDGs*
ordinal			ordinal value		level or rank
nominal			nominal value		presence/ absense

Figure 1.4–2: SDG indicators and their levels of measurement. The figure is designed to be read left-to-right. The colour scheme by level of measurement is reapplied in **Figure 1.6-1** and **Figure 1.7-1** for comparability.

1.5 Temporal Data: Representing Change

Time describes *when* an event occurred at a specific location or *when* the geospatial data was collected and enumerated. The temporal component of geospatial data indicates its currency, providing the time stamp or time interval during which location and attribute data are valid (see Section 3.9).

As with location and attribute data, the description of temporal data can be absolute or relative. ***Absolute time*** is measured by calendars and clocks; for example, the event occurred at 08:00 or lasted between 7 and 16 July. In contrast, ***relative time*** describes an event or period in comparison to others; for instance, the event happened after dinner or occurred before the start of summer. While mapping primarily relies on absolute time, relative time increasingly is employed in a storytelling approach to map design (see Section 4.7).

Absolute temporal data can be either ***linear***, where events proceed in a regular succession without repetition, or ***cyclical***, where sequences of events repeat in perpetuity (**Figure 1.5-1**). Human life from birth to death is linear, while the days of the week are cyclical. Linear temporal data typically are visualized on a timeline and cyclical temporal data are visualized as a circular clock called a coxcomb (see Section 3.14).

Usually the mapping purpose and audience interest are not focused on a single moment in time, but in ***change*** or a difference over time. Representing changes in geospatial data enables understanding of spatiotemporal patterns and trends. The United Nations update SDG indicator data annually to produce a linear ***time series*** or geospatial data on the same attribute collected recurrently over a regular time stamp or time interval (see **Figure 1.2-4**).

Analyzing and representing time series data is useful for assessing the impact of implementation programmes that support the SDGs as well as monitoring current progress towards meeting the goals.

There are three kinds of change based on the three components of geospatial data introduced in Section 1.2 (**Figure 1.5-2**). ***Location change*** includes movement but also expansion or shrinking, such as the changing areas of deforestation or protected habitats. ***Attribute change*** can be qualitative (e.g., same or different) or quantitative (e.g., increase or decrease) and is the primary focus when mapping SDG time series data. ***Existential change*** refers to appearance and disappearance over time, such as active mines or point pollution sources.

Changes can be represented using a single map, adjacent maps, and animation (see Section 3.9 and Section 4.8).

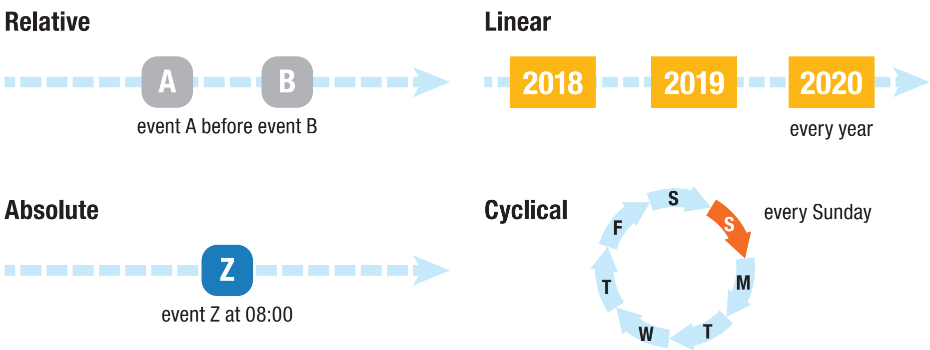


Figure 1.5-1: Time in geospatial data. **Left:** Absolute versus relative time. **Right:** Linear versus cyclical time.

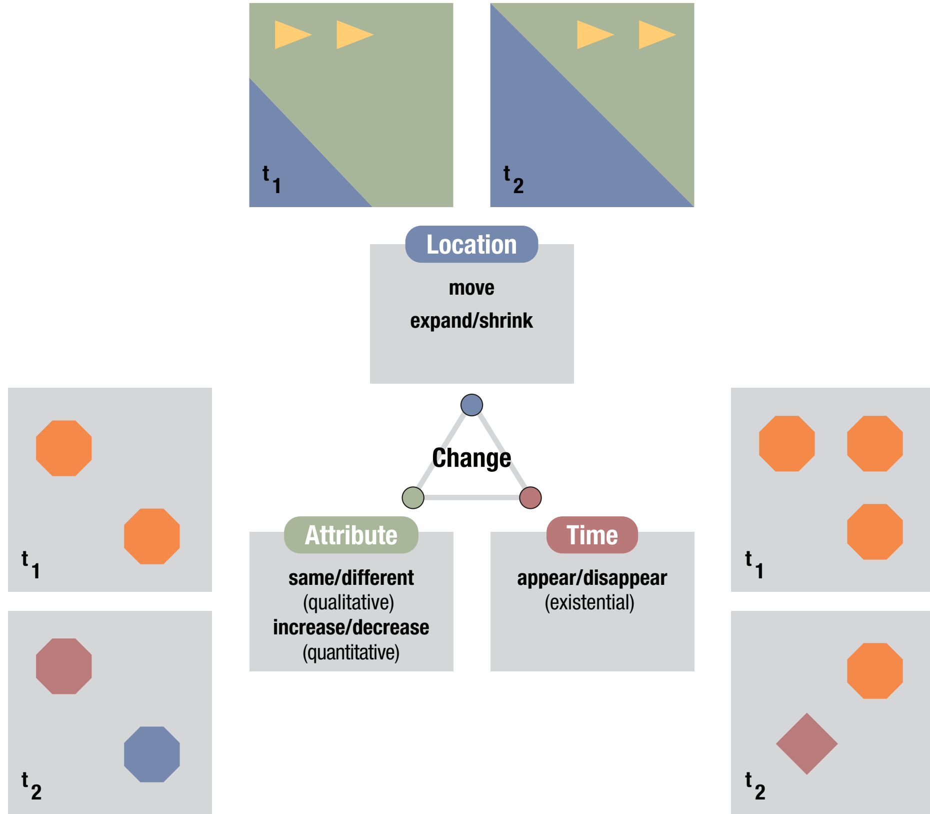


Figure 1.5-2. Change in geospatial data. There are three kinds of change based on the three components of geospatial data: location change (movement, shrinking, expanding), attribute change (same-different, increase-decrease), and existential change (appearance and disappearance).

1.6 Indicators Tiers & Their Data Characteristics

Not all of the 231 indicators have complete datasets in global coverage. Some indicators are not currently collected or shared by each country, while other indicators have not been defined coherently or collected uniformly. To make these data limitations clearer, the IAEG-SDGs classifies indicators into three ***tiers*** based on methodological consistency in collection and global data availability:

- ***Tier I:*** The indicator is conceptually clear, has an internationally established methodology, and standards are available. Data are regularly produced by countries for at least 50 per cent of countries and 50 per cent of the population in every region where the indicator is relevant.
- ***Tier II:*** The indicator is conceptually clear, has an internationally established methodology, and standards are available, but data are not regularly produced by countries.
- ***Tiering Pending:*** The indicator is awaiting a data availability review. "Tiering Pending" replaced the now deprecated "Tier III" used for indicators without an internationally established methodology or tested standards for collection.

As of April 2020, there were 115 indicators in Tier I, 95 in Tier II, and 19 Tiering Pending; two indicators were classified in more than one tier, making a total of 231. Great efforts are being made to bring more datasets into Tier I, but currently only Tier I indicators are mappable at a global scale.

Figure 1.6-1 shows all indicators and their tier categories.

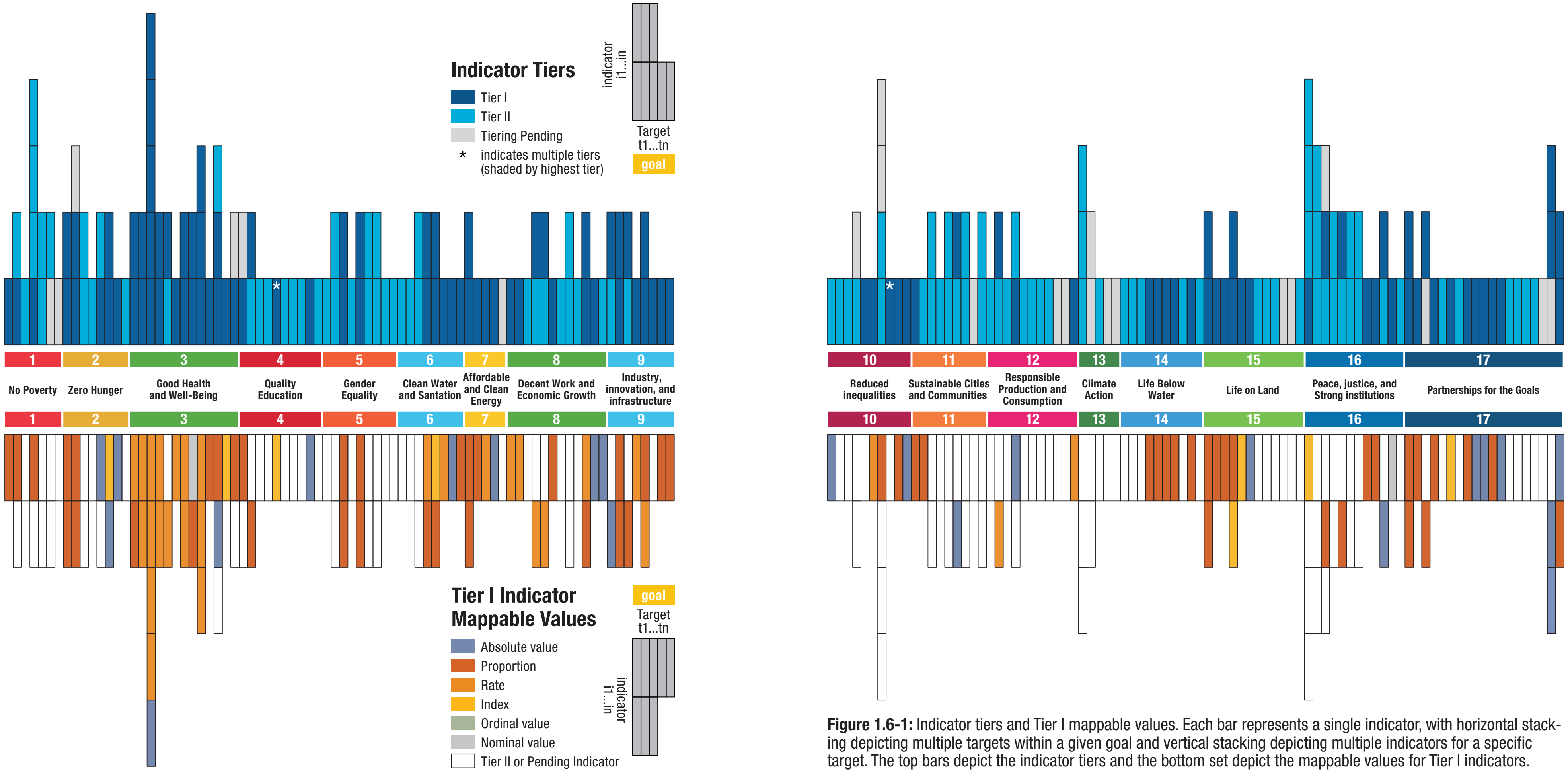


Figure 1.6-1: Indicator tiers and Tier I mappable values. Each bar represents a single indicator, with horizontal stacking depicting multiple targets within a given goal and vertical stacking depicting multiple indicators for a specific target. The top bars depict the indicator tiers and the bottom set depict the mappable values for Tier I indicators.

1.7 Data Transformation & Normalization

Data transformation describes the statistical conversion of an attribute, including a downgrade in level of measurement or normalization of absolute values into relative values (see Section 1.4). Data transformation is used to communicate a message in clearer statistical and visual ways. Data transformation also is useful for harmonizing multiple SDG indicators, allowing for their direct comparison in a bivariate map (see Section 3.7) or through a composite index.

Figure 1.7-1 works through potential transformation options for enumerated, population-based attributes. Data transformation only is recommended downward in the flowchart: absolute values can be transformed into relative values, relative values (e.g., proportions, rates, indices) into ordinal or nominal values, and ordinal values into nominal values.

Comparing a subset of the population to a count of the population results in a proportion (e.g., percentage of elderly). Comparing the same population attribute over time results in a change rate (e.g., percentage of increase or decrease). The combination of population and non-population attributes results in a per capita rate (e.g., hospitals per 100,000 inhabitants). Additionally, the combination of two non-population attributes results in other rates (e.g., number of cars per 100 km road). The combination of multiple attributes in a formula results in an index (e.g., gender inequality index based on health, empowerment, and labour-market data).

Each of the data transformations in **Figure 1.7-1** are acceptable ways to normalize absolute values. However, simply downgrading an absolute ratio value to an ordinal or nominal value does not normalize the data for mapping, as a conversion to a relative value is first needed. Other methods of normalizing an attribute include calculating an internal (e.g., mean, median, mode) or external (e.g., percentage above/below overall average) summary value.

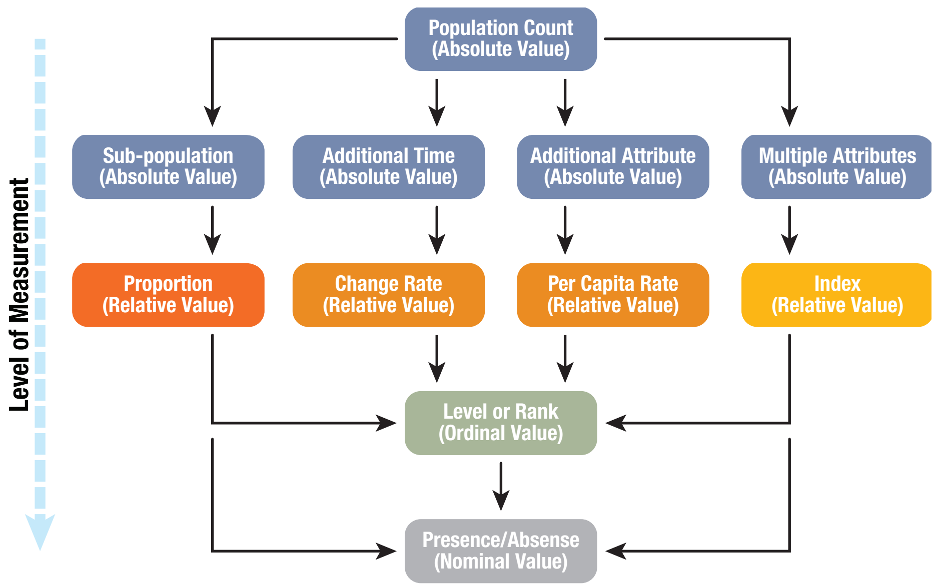


Figure 1.7-1: Data transformation options for enumerated, population-based attributes.

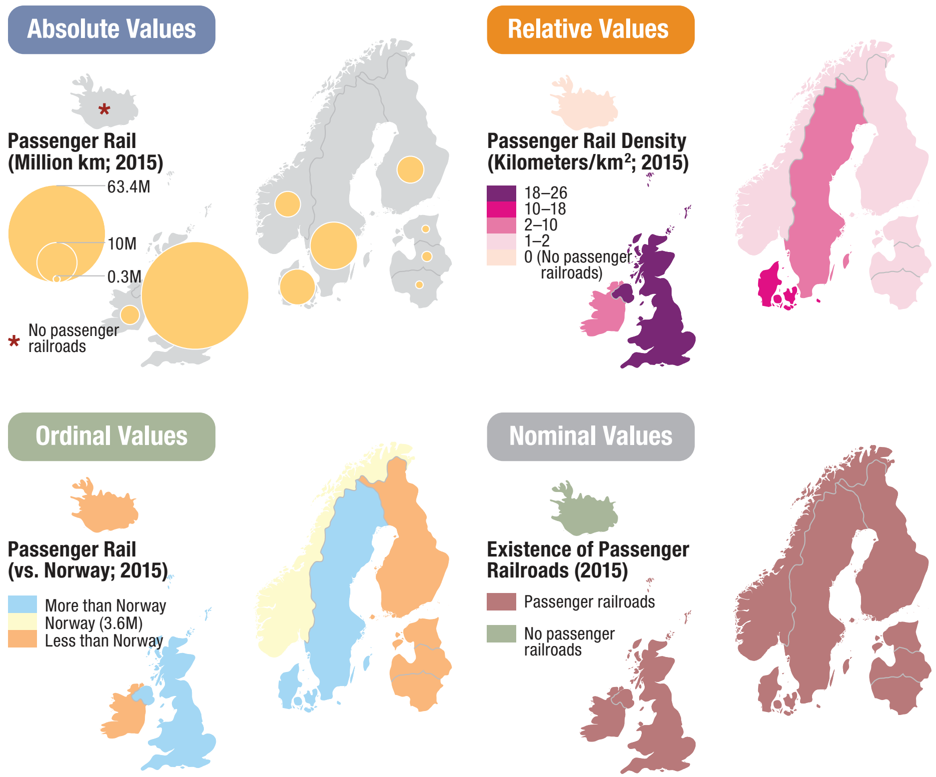


Figure 1.7-2: Data transformations for Indicator 9.1.2 (2015) on passenger rail volume. **Top-left:** Absolute values (total passenger rail in km). **Top-right:** Normalized, relative values (passenger rail in km per the country's total km² area). **Bottom-right:** Ordinal values (rank relative to Norway). **Bottom-right:** Nominal values (presence or absence).

Figure 1.7-2 shows the maps produced from transforming absolute ratio values to relative ratio, ordinal, and nominal values. As a result of the data transformation, the recommended map type switches from proportional symbol to choropleth when converting from absolute to relative (as choropleth maps require normalized data), from a sequential colour scheme to a diverging one when converting from ratio to ordinal (given the focus on the centre of the ordinal scale), and from a diverging to a qualitative colour scheme when converting from ordinal to nominal (see Section 2.10).

1.8 The Modifiable Areal Unit Problem & the Ecological Fallacy

As introduced in Section 1.4, most of the SDG indicator datasets contain enumerated attributes by country, making data transformation and normalization particularly important for mapping the SDGs. Normalization is critical for enumerated attributes because the same individual-level data when enumerated to different sets of polygonal boundaries results in different visual patterns in the map, an issue known as the ***modifiable areal unit problem*** (***MAUP***). In other words, the same underlying individual-level data when enumerated by different boundaries may lead to different findings, conclusions, or decisions derived from the map (**Figure 1.8-1**).

The two active factors in MAUP are the zone of aggregation (i.e., the arrangement and shape of the enumeration units) and the geographic scale (i.e., the size of the enumeration unit).

The ***zone of aggregation*** describes the arrangement and shape of the polygonal boundaries used for enumerating individual-level data. Enumeration units sometimes follow regularly gridded boundaries (e.g., lines of latitude or longitude) in North America and South America but mostly have irregular boundaries following natural features (e.g., rivers, mountain ranges) on other continents. Normalization from absolute values to relative values minimizes the impact of MAUP, ensuring visual comparability across enumeration units of varying in arrangement, shape, and size.

The ***geographic scale*** refers to the size and extent of a geographic phenomenon, such as the political boundaries used as enumeration units for the SDG indicators (see Section 2.6 for comparison of geographic to cartographic scale). The United Nations encourages collection of SDG indicator data at a local level, or ***small geographic scale***, with fine enumeration units having a detailed zone of aggregation. The SDG indicator data then is aggregated upward to a national level, or ***large geographic***

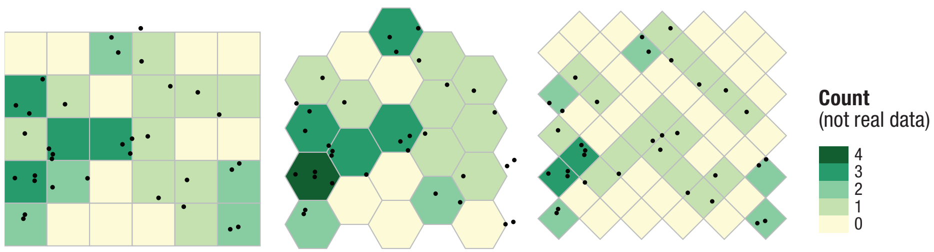


Figure 1.8-1: Understanding the modifiable areal unit problem (MAUP). The three images show the same, hypothetical point distribution enumerated by three sets of boundaries that differ in their arrangement, shape, and size. The shading shows the unnormalized count for each polygon unit, producing different visual patterns. **Left:** The pattern leans to the left. **Centre:** A clear cluster emerges in the bottom-left. **Right:** The pattern spreads more to the centre and right. Notably, choropleth maps require normalization (see Section 3.3) to reduce the visual impact of MAUP when shading the enumeration unit boundaries. Other thematic maps like dot density, isoline, and proportional symbol do not require normalization because their symbols are not tied directly to the enumeration unit boundaries.

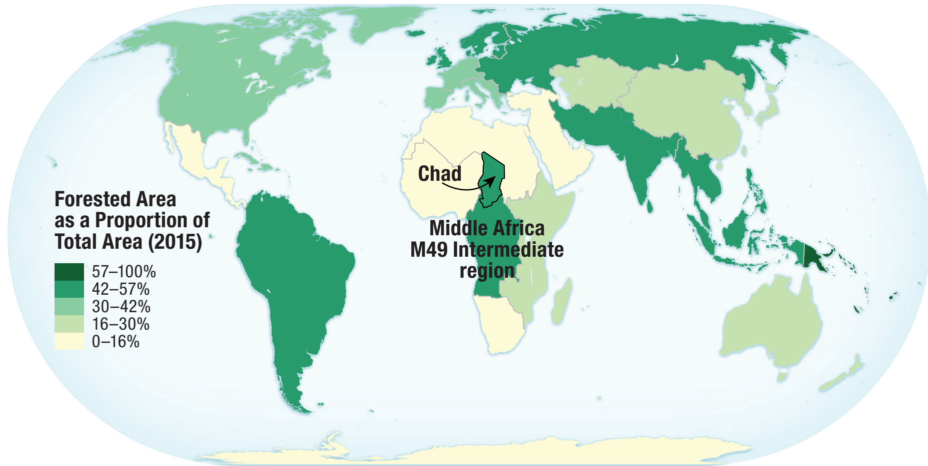


Figure 1.8-2: The effects of the modifiable areal unit problem and the ecological fallacy. Mapping Indicator 15.1.1 (2015) on forested area as a proportion of total area of the M49 sub-regions and intermediate regions rather than countries depicts an incorrect pattern of forestation in Middle Africa. Chad, an arid Sub-Saharan African country highlighted in the map, is only 5% forested but appears dark green in the resulting map given the tropic regions to the south also included within the "Middle Africa" intermediate region. In this case, the coarser resolution may lead to an incorrect understanding of forestation (and therefore deforestation) in Chad and the biogeography of Africa broadly. Unlike many of the SDG indicators, Indicator 15.1.1 has a muiltimodal rather than skewed distribution due to the high variability of precipitation by latitude. The resulting map uses an optimal breaks classification (see Section 1.9).

scale, with coarse enumeration units combining adjacent boundaries from the detailed zones of aggregation. Disaggregation from national- to local-level enumeration requires sophisticated mapping techniques such as dasymetric mapping (see Section 3.5), making it inappropriate to infer assumptions about local-level conditions from SDG indicator data on their own.

MAUP and geographic scale may result in the ***ecological fallacy***: the same individual-level data enumerated at different boundary resolutions (i.e., geographic scales) results in different statistical relationships in the enumerated attributes. Regarding the SDG indicators, perceived patterns across space for a given indicator and correlations between indicators may be an artefact of the arrangement, shape, and size of the enumeration units used to process and transform the data, not the actual geographic phenomenon the SDG indicator is designed to capture. For example, when aggregating SDG indicators from individual countries to M49 geographic regions, the resulting attribute data tells a different story about the region that some constituent countries may debate (**Figure 1.8-2**).

1.9 Data Classification

Classification describes the process of organizing map features into groups to improve legibility in the representation. Classification is one of the ways that cartographers generalize thematic maps, reducing visual complexity in the attribute data to clarify map patterns (see Section 2.7). However, classification also adds uncertainty into thematic maps (see Section 2.15), as the resulting patterns can be heavily influenced by the placement of ***class breaks*** (or division points between classes) within the scheme.

Classification applies to all attributes of all levels of measurement, including ordinal and nominal values (e.g., the Figure 1.7-2 ordinal map reclassifies all unique rankings to show only the ranking above and below Norway's value). Classification grows in difficulty when applied to numerical data. As with all aspects of cartographic design, a perfect classification does not exist, and all classifications have trade-offs. Instead, cartographers weigh several considerations to arrive at an appropriate ***classification scheme***, such as the portion of the distribution the cartographer wishes to emphasize, the total number of classes (with most schemes using four to seven classes), and critical values that produce rounded or meaningful class breaks.

For SDG indicators reported as absolute values, proportions, rates, and indices (see Section 1.6), always inspect the distribution of the attribute across enumeration units before choosing a classification scheme (Figure 1.9-1). Different numerical classification schemes are recommended for different attribute distributions, including ***arithmetic*** or ***geometric*** for skewed attribute distributions, ***equal interval*** for uniform attribute distributions (Figure 1.9-2), ***optimal breaks*** for multimodal attribute distributions (Figure 1.9-3), and ***mean & standard deviation*** for normal attribute distributions (Figures 1.9-4).

A ***quantile*** scheme is useful for comparing multiple indicators that are on different scales or for ordinal level attributes (Figure 1.9-5). Figures 1.9-2, 1.9-3, 1.9-4, and 1.9-5 reclassify the Figure 1.9-1 data, showing how the classification impacts the resulting map.

Because many of the SDG indicators exhibit a left- or right-skew in their attribute distribution—with many countries clustering together on one end of the scale with several extreme outliers—the arithmetic scheme currently is most common for SDG indicator data. However, if extreme global inequities are mitigated in the future, the SDG indicator data will exhibit a more uniform or normal data distribution, leading to increased use of the equal interval or mean & standard classification schemes.

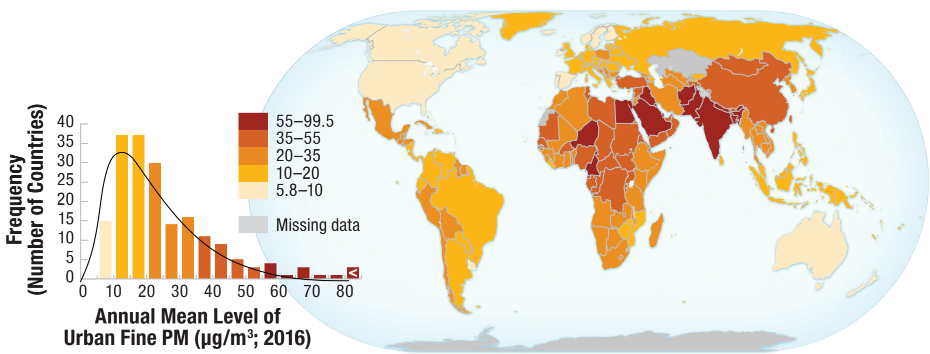


Figure 1.9-1: Data distributions and classification. **Left:** The histogram depicts the left-skewed attribute distribution for Indicator 11.6.2 (2016) on the annual mean levels of urban fine particulate matter. **Right:** The resulting arithmetic scheme increases distances between class breaks in a regular progression, here expanding each class width by 5 µg/m3 to provide more detail for features in the clustered side of the distribution rather than emphasizing outliers.

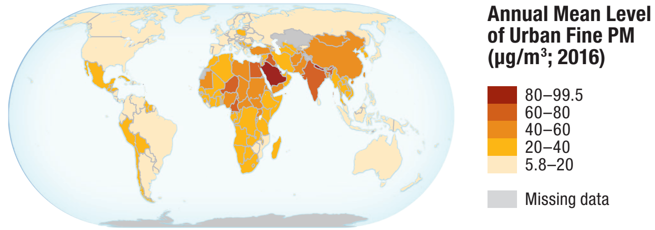


Figure 1.9-2: Equal interval. Equal interval places class breaks equidistant from each other. Use equal interval for indicators with a uniform distribution. Equal interval has the added advantage of resulting in simple, easy-to-understand map legends good for general audiences.

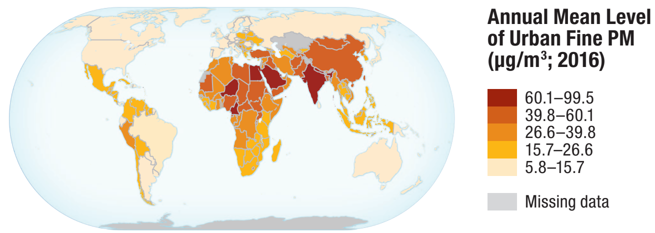


Figure 1.9-3: Optimal breaks. Optimal breaks treats classes like clusters, minimizing differences within the class while maximizing differences among classes. Use optimal breaks for indicators with multiple clusters in the distribution or to emphasize outliers (e.g., Figure 1.8-2).

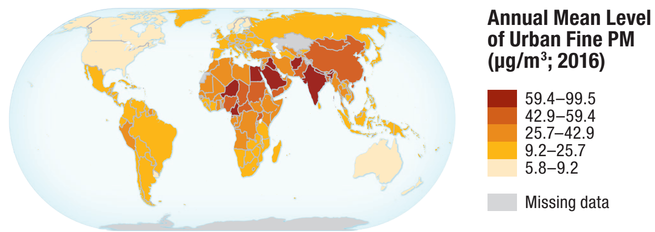


Figure 1.9-4: Mean & standard deviation. Mean & standard deviation is a variant of equal interval in which the equal interval is in standard deviations from the mean. Use mean & standard deviation for indicators with a normal distribution or when the mean value is meaningful.

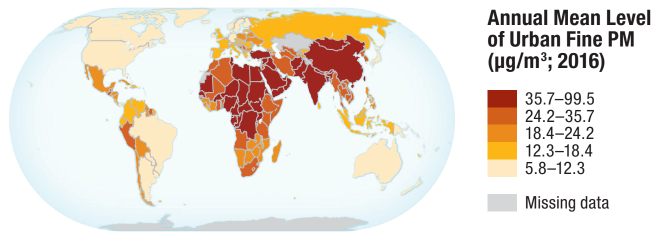


Figure 1.9-5: Quantile. Quantile places the same number of features into each class. Use quantile for side-by-side or bivariate comparison of multiple indicators, as the scheme effectively reduces numerical attributes to similar ordinal scales, or when the median value is meaningful.

GOAL 1: END POVERTY IN ALL ITS FORMS EVERYWHERE

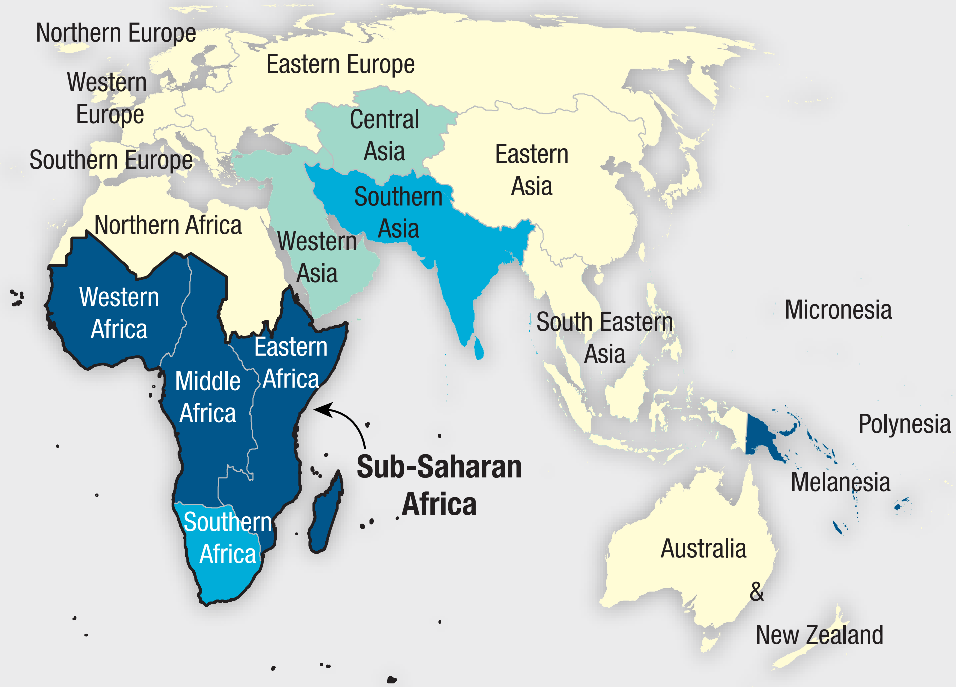
SDG Target 1.1
Eradicate extreme poverty for all people everywhere

▶ 736 million people lived in extreme poverty in 2015

▶ Most people that earn less than 1.90 USD per day live in Sub-Saharan Africa

Proportion of Population Living Below the International Poverty Line (most current value 2012–2018)

- 30–53%
- 20–30%
- 10–20%
- 5–10%
- 0–5%
- Missing data
- Sub-Saharan Africa



▲ The map depicts Indicator 1.1.1 (most current value 2012–2018) on the proportion of population living below the international poverty line (set at 1.90 USD per day) as a choropleth by SDG groupings. The M49 standard is a multi-level, global set of region, sub-region, and intermediate region groupings for obtaining greater homogeneity in sizes of demography. The SDG groupings are derived from the M49 methodology and use a combination of regions and sub-regions.

Indicator 1.1.1 is a ratio level, relative value (a proportion) and, thus, is normalized for choropleth mapping to mitigate effects from the modifiable areal unit problem. The choropleth map uses an arithmetic classification for the left-skewed attribute distribution and a sequential colour scheme for an apparent increase from low to high.

◀ The UN Secretary-General meets people living in a camp for internally displaced persons (IDPs) in the town of Bangassou, Central African Republic. (Source: UN Photo/Eskinder Debebe, 2017)

1 NO POVERTY

SECTION 2: MAP DESIGN CONSIDERATIONS

2.1 Content Selection

Designing a map is not a trivial task. Before design begins, the cartographer makes several important decisions about the data content included in the map, which subsequently inform map design and use decisions. ***Selection*** is a form of generalization that determines the retention or removal of map features (e.g., different SDG indicator datasets; see Section 2.7).

First, the cartographer should ask "Why are we making this map?" and "What is the take-home message or main point of the map?". The map should have a clear ***subject*** defining its *who*, *what*, *when*, and *where*, or the spatiotemporal context, for the map (see Section 1.2). For the SDG indicators, this includes selecting map content for one or several SDG indicator datasets (i.e., attribute content selection), country or regional enumeration units using the M49 codes (i.e., location content selection), and one or several time stamps in the time series (i.e., temporal content selection) (see **Figure 1.2-4**). The map also should have a specified ***purpose***, or overall goal, in producing the map that can vary from specialist exploration to external communication for policy and decision-making or public awareness and outreach (see Section 4.1).

Second, the cartographer should ask "Who is the map designed to support?".

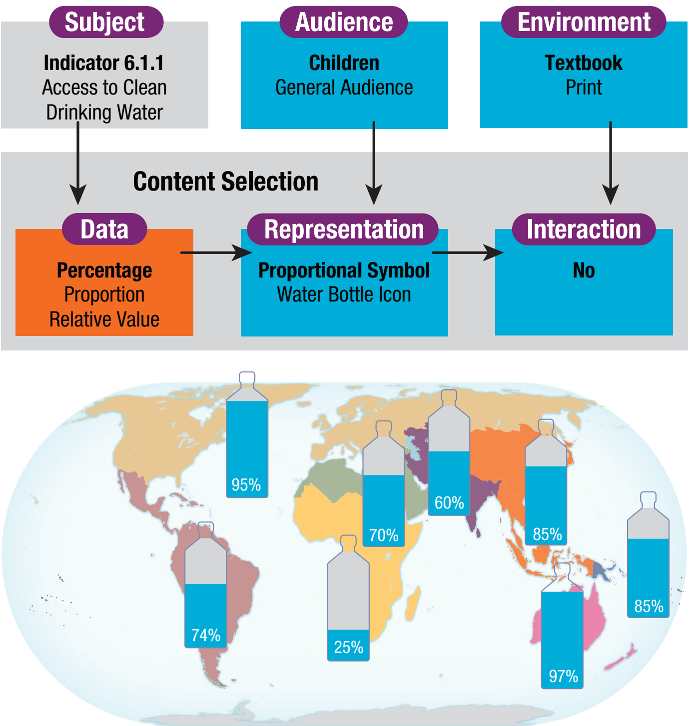
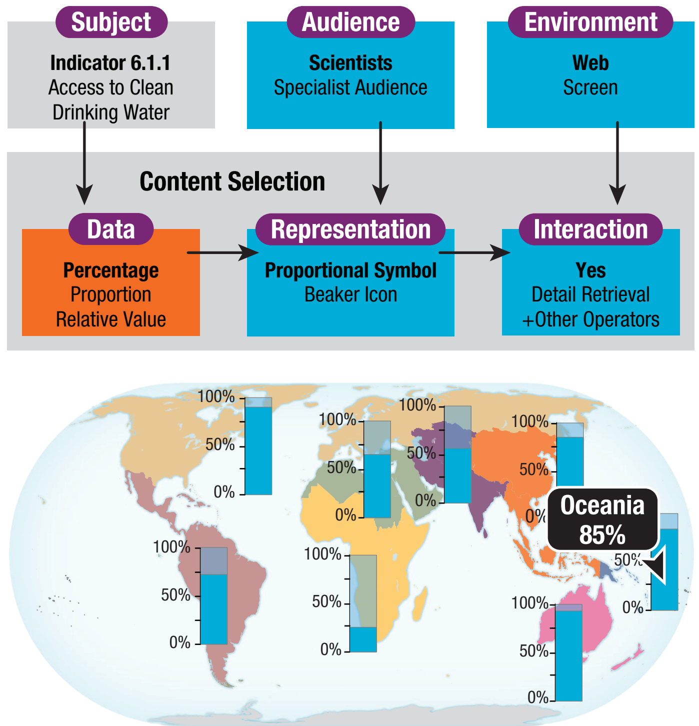


Figure 2.1-1: Content selection. The pair of selection workflows and resulting maps demonstrate how maps of the same subject may vary based on differences in audience and map use environments. In both maps, the subject is Indicator 6.1.1 (2015) on the percentage of population with access to clean drinking water.

The identified ***audience***, or intended users of the map, influences many cartographic design choices. For instance, a map designed for children requires simplified content and a playful design compared to a map designed for scientists or policymakers (**Figure 2.1-1**). Supporting all audiences with a single map is rarely possible—making optimal content selection highly contingent on the audience—but understanding the individual differences across prospective target audiences actually clarifies rather than confuses the design process (see Section 4.1).

Finally, the cartographer should ask "How will the map be used?" and "Will the map appear on paper as a poster or report or onscreen over the internet or on a mobile device?". The map use ***environment*** places additional constraints on the design. Map use environments have changed rapidly with the ubiquity of personal computing and smartphones, yet digital devices typically cannot display the same density of content as paper. When they can, such detail in content comes at the cost of heavy mobile data transfer and slowed loading and rendering times. Thus, cartographers now need to consider more design media (e.g., paper, projectors, screens) as maps respond across environments as well as more viewing conditions as maps move through variable environments.

Left: A general audience of children results in selection of a playful water bottle proportional symbol, but printing in a textbook means no digital interaction. **Right:** A specialist audience of scientists results in selection of a more complex beaker proportional symbol, and distribution online allows for exploratory interaction.



2.2 Project Planning & the Cartographic Design

A ***project plan*** outlines the series of steps from conceptualization to final delivery during cartographic design. Planning each step in the cartographic design process might seem unnecessary and tedious at first, but it typically saves time and resources. Project planning also provides a chance to assess project goals, such as the map subject, purpose, audience, and map use environment at the start of the project, intentionally slowing down design to consider a range of alternatives (see Section 2.1). Finally, project planning also provides opportunity to invite all relevant stakeholders to the table and participate in the cartographic design process, which might include representatives from target audiences to ensure user needs are met for more complex interactive, online, and mobile mapping projects (see Section 4.12 for an explicitly user-centred design process).

Even with a detailed project plan, it is still highly likely that unexpected challenges will arise. Challenges may include limitations in data coverage and format, data availability (and constraints) of mapping software, and complexity in data analysis. Importantly, always survey and inspect availability data before deciding on a specific type of map to make. It is easy to outline most details of the map design only to realize you cannot meet your mapping goals with the available data. It is impossible to mitigate all challenges, but project planning sets important milestones to keep the project moving forward as well as identifies moments of critical reflection and evaluation to improve the final map product.

Figure 2.2-1 provides a general overview of the cartographic design process. A specific project plan varies based on the given mapping context. **Figure 2.2-2** provides a more detailed project plan for mapping SDG indicators, forming a "checksheet" that can be adapted and reused for specific mapping needs.

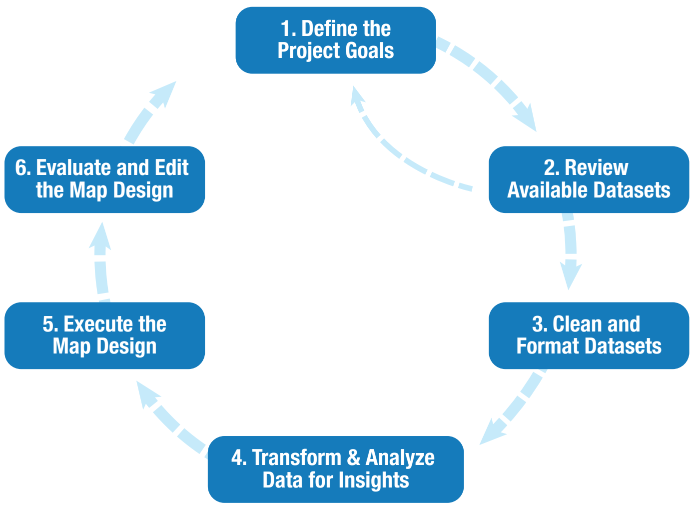


Figure 2.2-1: A general cartographic design process. The cartographic design process outlined here is common for static, print mapping. Recommendations for interactive, online, and mobile mapping are provided in Section 4.12.

Figure 2.2-2 (Opposite side): A checksheet for mapping SDG indicators. Adapt and reuse this project plan for specific mapping needs.

1. Define the Project Goals

[ ] Research prospective SDGs, targets, and indicators relevant to your project. Cast a wide net when reviewing background materials, including official United Nations documentation, existing maps and diagrams on the topic, and reference material from geography, cartography, and related domains.
[ ] Invite relevant stakeholders and target audiences to discuss the project goals and project plan.
[ ] Consider alternative designs for communicating the main idea of your map and possible alternative interpretations by the target audience.
[ ] Determine the intended map subject, purpose, audience, and map use environment.

2. Review Available Datasets

[ ] Review and collect official SDG indicator data from: https://unstats.un.org/sdgs/indicators/database/
[ ] Identify alternative data sources that offer the best approximations for your map goals if SDG indicator data are unsatisfactory, particularly for Tier II and untiered indicators.
[ ] Collect ancillary datasets, including location boundary datasets, ancillary datasets supporting advanced geospatial analyses and map interpretation, and non-geospatial datasets that support the map purpose.
[ ] Modify the map goals based on available data.

3. Clean and Reformat the Data

[ ] Identify the mapping software for your project; this decision will influence the type of data cleaning and formatting required
[ ] Narrow the scope of your location, attribute, and temporal data through data filtering.
[ ] Assess the completeness of the data and identify ways to manage missing data and other uncertainties.
[ ] Join attribute and temporal data to location boundaries in mapping software for analysis and presentation.

4. Transform and Analyze the Data for Insights

[ ] Perform necessary data transformations to align attributes.
[ ] Normalize enumerated data for specific thematic map types (e.g., choropleth maps).
[ ] Apply an appropriate classification scheme based on the data distribution and map purpose.
[ ] Identify noteworthy patterns, trends, and anomalies in the data.

5. Execute the Map Design

[ ] Identify the appropriate symbolization and map type based on the map purpose and applied data transformations.
[ ] Choose an appropriate projection based on the map purpose, geographic extent, and identified map type (e.g., equal-area for dot density, choropleth, and shaded isoline maps).
[ ] Set the cartographic scale and generalize the location data for this scale.
[ ] Develop a coherent visual hierarchy and aesthetic style.
[ ] Place and style map labels to reinforce the visual hierarchy and provide context for interpreting the map.
[ ] Add additional annotations to clarify important patterns, trends, and anomalies relevant to the map purpose.
[ ] Add a legend and additional map elements, such as indications of north and cartographic scale, but only if important to interpreting the map.

6. Evaluate and Edit the Map Design

[ ] Compare the draft map design to your initial project plan and map goals.
[ ] Complete a self-edit to identify misspelled place names, missing symbols, misaligned linework, etc.
[ ] Invite relevant stakeholders and target audiences to provide input and feedback on the draft map design.
[ ] Revise the map design based on internal and external feedback.

2.3 Cartographic Design Decisions

In cartography, ***design*** refers both to the *process* in planning, executing, and evaluating a map as well as individual *decisions* that a cartographer must make during the process to represent the selected geospatial datasets visually. In this regard, a ***representation*** is a thing (e.g., a map or diagram) that stands for another thing (e.g., real-world geographic phenomena and processes). Design decisions are how a cartographer asserts their positionality and situated perspective, making all resulting maps authored and subjective rather than neutral or objective.

Design also refers to the final *product* of the cartographic design process. Accordingly, a ***map*** is defined as an abstracted (see Section 2.6 and 2.7) and authored (often) visual representation of geographic phenomena or processes (see Section 1.2). Geospatial data, too, are authored, abstracted, and made visible when mapped or visualized in another diagram. Because maps are authored, the same subject can be mapped in a number of different, equally acceptable ways (e.g., Figure 1.7-2). However, some design decisions are suboptimal for particular mapping contexts, and the following sections offer design recommendations to avoid common pitfalls in cartographic design rather than enforce hard-and-fast rules.

The **Figure 2.3-1** workflow identifies some of the data and representation decisions made during the design process of the **Figure 2.1-1** children's map of access to safe drinking water.

First, establish the level of measurement of the SDG indicator dataset (**Decision 1**). Indicator 6.1.1 is defined as the percentage of people having access to clean drinking water services, a relative value reported at a ratio level (see Section 1.4). Next, decide if the geospatial data supports making a map, or if representation is limited to diagrams of the attribute or temporal data components (**Decision 2**). The map purpose includes the spatial distribution and unevenness of access to safe drinking water, requiring a map for this kind of interpretation.

Once a map is selected, identify a viable set of enumeration units for the map subject and audience (**Decision 3**), such as the SDG regional groupings (see Section 1.3), and other basemap information needed for context. Then, choose an acceptable way to represent the indicator as a thematic map (**Decision 4**). Proportional symbol maps depict discrete, abruptly changing phenomena, such as point sources (i.e., wells) of clean drinking water, evoking an appropriate visual metaphor for Indicator 6.1.1 (see Section 3.1).

These initial design decisions then inform subsequent decisions. For instance, proportional symbol maps of SDG indicators can be applied at the point or polygon dimensionality (see Section 2.8), but the latter use of polygons results in a cartogram that is too unfamiliar a map for children (see Section 3.8), making points the better choice (**Decision 4**). Proportional symbols primarily rely on the visual variable size (see Section 2.9), and redundantly encoding Indicator 6.1.1 with other visual variables like colour hue prevents the stylist use of blue for water (**Decision 5**). Not all decisions are contingent on the thematic map type, as a proportional bar rather than a proportional circle (both proportional symbols) is selected to emphasize the relative values (percentages) instead of absolute values (**Decision 6**). Finally, the bar is styled as a water bottle for a playful representation for children (**Decision 7**).

Changing an earlier decision impacts other decisions: switching to a choropleth map changes the symbol dimensionality to polygons and the visual variable to colour value, but continues to use the normalized relative value. Design therefore is highly iterative, but more planning early in the process results in fewer iterations during design.

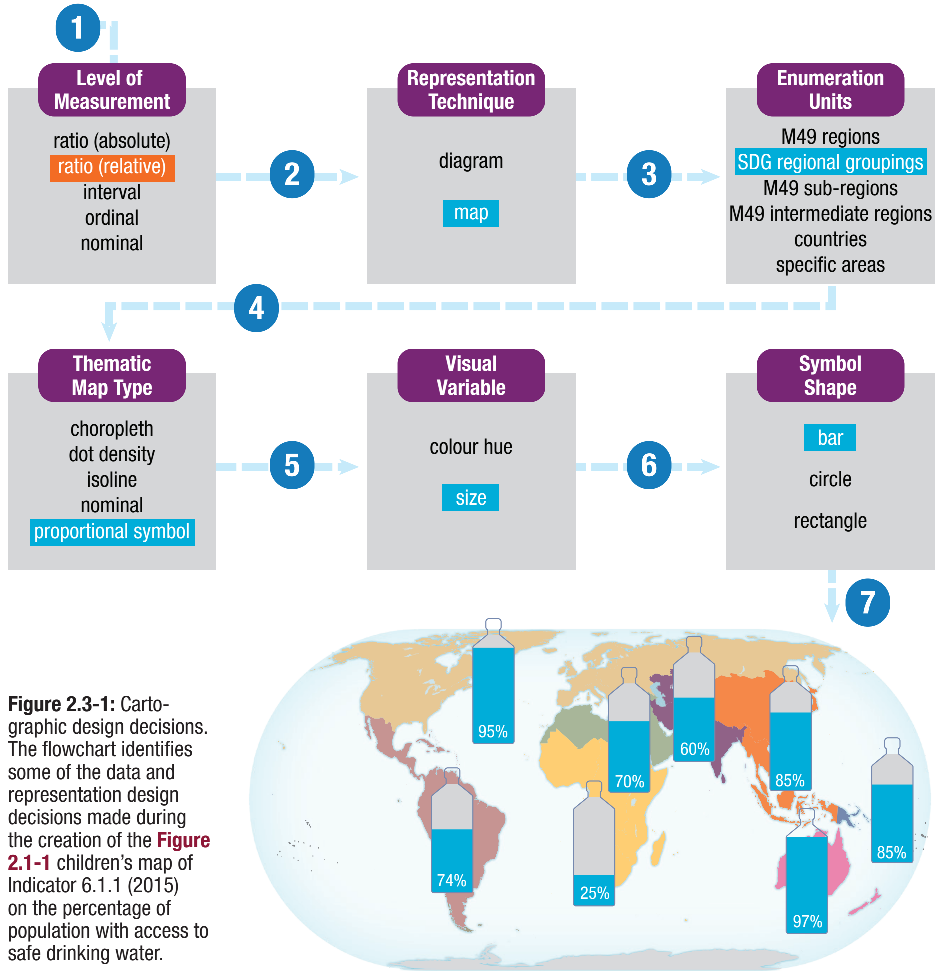


Figure 2.3-1: Cartographic design decisions. The flowchart identifies some of the data and representation design decisions made during the creation of the **Figure 2.1-1** children's map of Indicator 6.1.1 (2015) on the percentage of population with access to safe drinking water.

2.4 Map Projections

Projection is the process of transferring geospatial data from a three-dimensional model of the Earth to a two-dimensional or "flat" map. While the projection process is mathematical and completed computationally, projections often are characterized by the shape of the map surface as it conceptually intersects the globe (**Figure 2.4-1**).

A ***cylindrical*** projection conceptually wraps the map surface completely around the globe, with the unfurled surface resulting in a rectangular graticule. Because normal cylindrical projections intersect the globe at or near the equator, they minimize distortion for regional maps of equatorial regions.

A ***conic*** projection conceptually wraps the map surface around one hemisphere of the globe, resulting in a semi-circular graticule. Normal conic projections minimize distortions for regional maps of the mid-latitudes.

A ***planar*** projection conceptually places the map surface on the globe, resulting in a circular graticule after projection. Normal planar projections minimize distortions in the polar regions.

Choosing a projection is a critical cartographic design decision because all projections distort one or several map properties through this transfer.

A ***conformal*** projection preserves angular relationships at infinitely small points. Conformal projections often are used as a proxy for preserving the shape of polygon features although two different conformal projections result in differently shaped features. Cylindrical conformal projections, like the Web Mercator, are common for web maps because the graticule disassembles into consistently shaped square tiles (see **Section 4.5**), heavily distorting areas as a result.

An ***equivalent*** or ***equal-area*** projection preserves the relative areas of polygon features, often heavily distorting shape as a result. Thematic maps

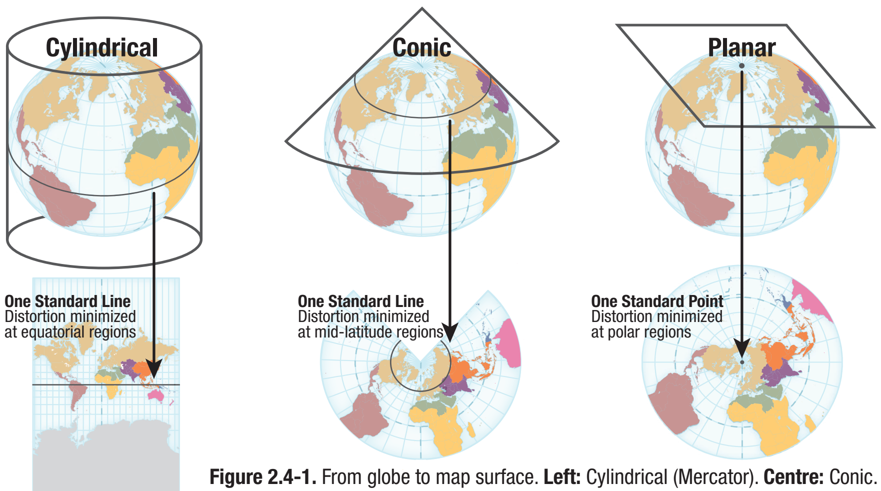


Figure 2.4-1. From globe to map surface. **Left:** Cylindrical (Mercator). **Centre:** Conic. **Right:** Planar. The graticule and standard lines or points are marked for comparison.

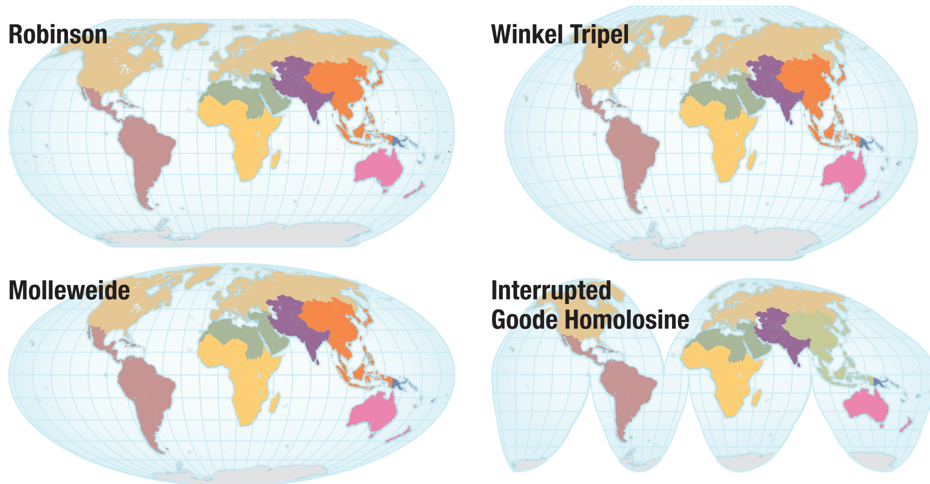


Figure 2.4-2. Some alternative world projections to the Eckert IV. **Top-left:** Robinson (compromise). **Top-right:** Winkel-Tripel (compromise). **Bottom-left:** Molleweide (equivalent). **Bottom-right:** Interrupted Goode Homolosine (equivalent). Note how the changing graticule provides an indication of the projection distortion across the map.

that rely on colour shading of areas (e.g., choropleth maps, shaded isoline maps) or density normalization by area (e.g., dot density maps) must use an equivalent projection to avoid distorting the relative amounts of the symbols across the map (see **Section 3.1**).

An ***equidistant*** projection preserves distance from either one point (planar) or two points (cylindrical and conic) to all other points on the map. Distance also is preserved for all projections at a ***standard point*** (for tangent planar projections only; see **Section 2.5**) or ***standard line***, or the locations where the 2D map plane touches or intersects the 3D globe (**Figure 2.4-1**). Therefore, cartographic scale is only accurate along a small number of transects in the map (see **Section 2.6**).

An ***azimuthal*** projection preserves directions from a single point to all other points on the map, a distortion that is different from the conformal preservation of all angles at infinitely small points. All azimuth projections are planar, and vice versa, and, therefore, these terms often are interchangeable in mapping software.

Finally, a ***compromise*** projection balances distortion across all map properties.

Projections often are named in mapping software for the map surface used and the map property maintained (e.g., "conformal conic"), so understanding these concepts is helpful for choosing an appropriate projection.

In the context of the SDGs, the primary concern when choosing a projection is finding a balanced and equitable representation for all countries depicted in the map. Therefore, compromise or equivalent projections are recommended for world SDG maps (**Figure 2.4-2**). This book primarily uses the equivalent Eckert IV projection for world SDG maps.

2.5 Projection Centring

The ***central meridian*** of a map projection is the longitude along which the map surface of a projection is focused (see Section 1.2). A 0° central meridian at Greenwich, England, often is selected for world maps since it is the zero reference, or ***prime meridian***, for east-west notations of longitude. The ***equator*** is the zero reference for north-south notations of latitude (**Figure 2.5-1**).

Choosing an alternative central meridian shifts the map's focus to a different area of interest potentially more appropriate for the given subject, purpose, and audience. **Figures 2.5-2** and **2.5-3** compare two perspectives on the same SDG indicator. These views tailor the map to more local audiences, placing China and Canada in the centre of the world, respectively, by changing the central meridian of the projection.

Choosing an alternative central meridian also clarifies map features and spatial relationships. For instance, **Figure 2.5-2** splits Canada, with part of the country at the far left of the map and part at the far right. Adjusting the central meridian slightly eastward into the Pacific Ocean maintains a general focus on China while also avoiding broken linework in other continents, improving map interpretation. The Eckert IV world map projection in this book uses a central meridian of 11° E to avoid breaking continents (**Figure 2.5-4**).

Projections do not need to be centred on a single meridian. The ***aspect*** of the map surface to the globe can be rotated from a ***normal*** orientation around the Earth's axis of rotation, which results in standard parallels. A ***transverse*** aspect rotates the map surface 90° from normal, instead resulting in standard merdians. An ***oblique*** aspect describes other rotations between normal and transverse, such as the orthographic projection giving the appearance of a view from space (e.g., the "globes" in **Figure 2.4-1**).

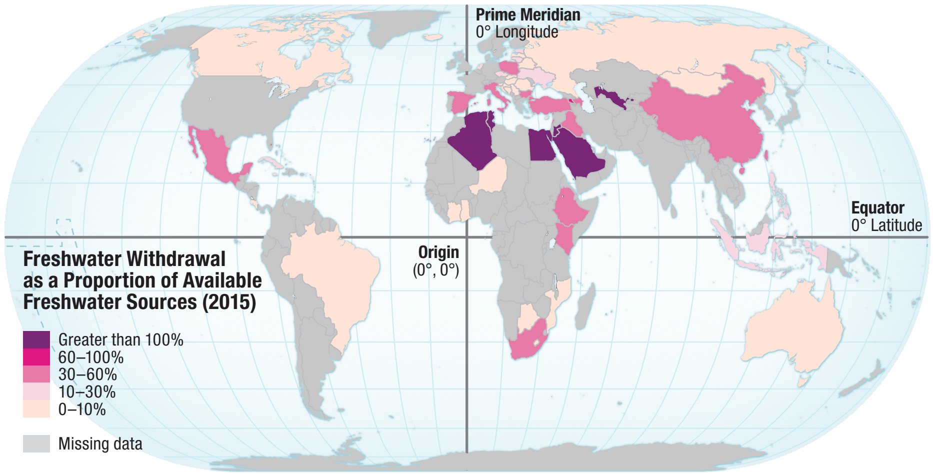


Figure 2.5-1: Projection Centring. The map of Indicator 6.4.2 (2015) depicts freshwater withdrawal by country. The map uses the prime meridian, or 0° longitude, as the central meridian. The equator, or 0° latitude, also is marked.

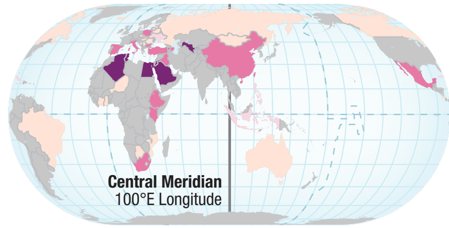


Figure 2.5-2: Centring on China. The map reprojects the **Figure 2.5-1** map of Indicator 6.4.2 (2015) using a central meridian of 100° E. Such map centring tailors the map to a local audience, here China, with the tradeoff of making the values of countries in North America, like Canada, more difficult to interpret.

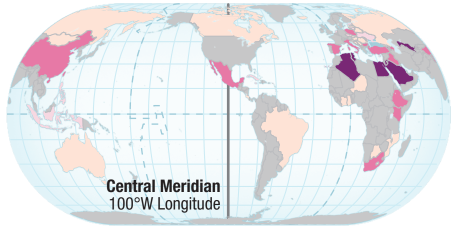


Figure 2.5-3: Centring on Canada. The map reprojects the **Figure 2.5-1** map of Indicator 6.4.2 (2015) using a central meridian of 100° W, changing the local perspective to Canada. Because **Figures 2.5-1**, **2.5-2**, and **2.5-3** use the equivalent Eckert IV projection, the sizes of China and Canada (and all other enumeration units) remain the same across the three maps, despite the shape of these countries changing dramatically when recentred.

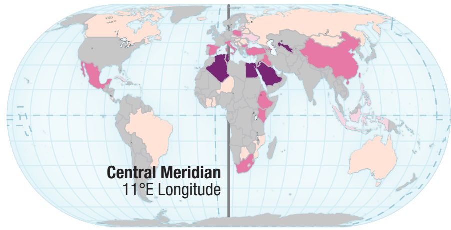


Figure 2.5-4: Centring on 11° E. When world SDG maps are made for a global audience, or when a local audience does not impact the purpose of the map, a normal, equivalent projection centred on 11° E is recommended. An 11° E centring splits the Pacific Ocean, resulting in improved visual balance of negative space for continental datasets. While an 11° E centring avoids breaking many country boundaries, some Small Island Developing States are impacted.

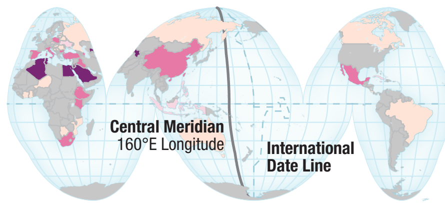


Figure 2.5-5: Interrupted projection centred on 160° E. Rather than breaking the map at a single meridian, an interrupted projection slices the map surface into lobes, with each lobe having its own central meridian. The figure depicts the **Figure 2.5-1** map of Indicator 6.4.2 (2015) using the Interrupted Goode Homolosine projection. Lobe centring is selected to focus on oceans rather than continents, making it a useful projection for depicting Small Island Developing States.

Rather than touching at a single ***tangent*** point (for planar projections) or line (for conic and cylindrical), the map surface also can slice into the globe. Such ***secant*** projections are common because they result in one standard line (for planar) or two standard lines (for conic and cylindrical), reducing distortion overall.

Finally, ***interruptions*** also can be added to the projection to reduce local distortions in each resulting map lobe. Interruptions help to centre the map primarily on land versus ocean phenomena. **Figure 2.5-5** shows the world in the Interrupted Goode Homolosine projection, updating the **Figure 2.4-2** with a central meridian of 160° W to emphasize the Small Island Developing States.

2.6 Cartographic Scale

Cartographic scale is the ratio between a distance represented on a map and the corresponding distance in the real world. Cartographic scale often is indicated numerically by a ***representative fraction*** between the map and real-world distance. For example, a map with a cartographic scale of 1:1,000,000 means that 1 cm on the map is equivalent to 1,000,000 cm (10 km) in the real world. A ***verbal statement*** such as “1 cm equals 10 km” often accompanies the representative fraction on the map to make the relationship between the map and the real world conceptually easier to understand by using plain language. Alternatively, a ***scale bar*** provides a graphic indication of cartographic scale using a line to show a benchmark distance (**Figure 2.6-1**).

Today, a scale bar is more common than a representative fraction or verbal statement since it is the only indication of scale that can be posted digitally for viewing on variable screen sizes: as the size of the screen changes so does the size of the graphic scale bar along with the map. In contrast, the representative fraction or verbal statement only remains true at the original printed map size. A scale bar has the added benefit of providing a visual affordance when interactively zooming across a multi-scale web map (**Section 4.3**), orienting the user to changes in the level of detail among scales (**Figure 2.6-2**).

Importantly, cartographic scale is the conceptual inverse from geographic scale (introduced in **Section 1.8**) and often are confused in day-to-day speak. ***Small cartographic scale*** describes a representative fraction that computes to a small decimal number (e.g., 1:1,000,000=0.000001), whereas a ***large cartographic scale*** computes to a relatively larger decimal number (e.g., 1:1,000=0.0001; 0.0001>0.000001). Thus, a map at a small cartographic scale depicts large geographic scale

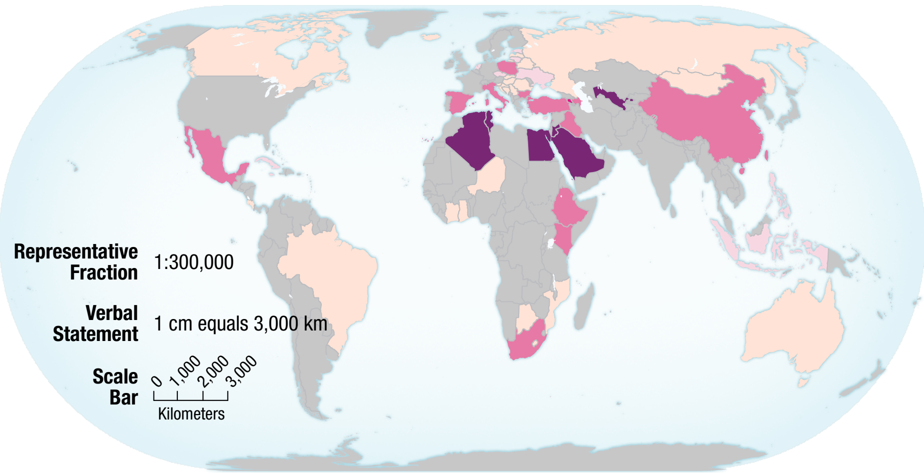


Figure 2.6-1: Indicators of scale. Three indicators of scale are included for the **Figure 2.5-1** map of Indicator 6.4.2 (2015) freshwater withdrawal by country. Only the scale bar is useful for the digital version of this book.

Figure 2.6-2: Cartographic scale on web maps. Web maps enable users to zoom interactively across cartographic scales. Cartographic scale progresses from large to small from top-left to bottom-right. (Source: OpenStreetMap).

phenomena and so is susceptible to the modifiable areal unit problem and ecological fallacy. Because web maps enable multi-scale zooming, cartographic scale instead is described as “zoom level” in web map design (see **Section 4.5**).

The subject and purpose of the map influences the appropriate cartographic scale (see **Section 2.1**), and the selected cartographic scale in turn influences the appropriate projection (**Section 2.4**) and the amount of generalization (**Section 2.7**). Cartographic scale only is accurate at the standard points or lines and, therefore, the indication of scale is never “true” across the entire map. The severity of distortion increases at smaller cartographic scales as more of the world is depicted on a single map. Accordingly, an indication of cartographic scale often is left off small cartographic scale maps such as the world maps in this book.

2.7 Generalization

Generalization is the process of meaningfully removing detail from the map to support the map's purpose, audience, and use environment (see Section 2.1). Maps are useful not because they show all of reality in its entire complexity, but because they intentionally remove detail to make the subject as clear as possible. Generalization usually is applied when moving from larger to smaller cartographic scales (see Section 2.6), but also can be applied stylistically (see Section 2.14).

In digital mapping, generalization can be applied to the attribute, temporal, and, most commonly, location components of geospatial data. Some data sources already are generalized to multiple cartographic scales, such as the M49 hierarchy of enumeration units for reporting indicators.

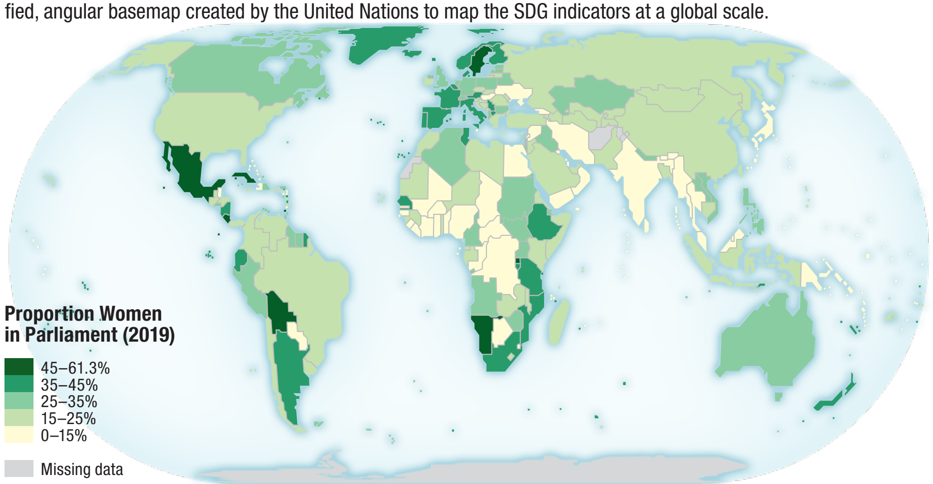
When geospatial datasets are not already generalized to the cartographic scale, ***generalization operators*** can be applied to the dataset to reduce complexity and maintain legibility for the resulting map design.

Selection is the first generalization operator to consider during map design. As introduced in Section 2.1, selection describes the retention or removal of different map feature types based on the map purpose, audience, and map use environment. With the possibility of interactive, online, and mobile maps, it can be helpful during project planning to organize content selection by the included datasets, appropriate representation techniques, and supported interactive functionality (see Figure 2.1-1).

Several generalization operators alter the vector geometry of the geospatial data used in the map (see Section 1.3). For instance, ***simplify*** reduces the number of nodes that constitute a feature, reducing complexity in the vector geometry while losing absolute location accuracy deemed unnecessary for the given cartographic scale (Figure 2.7-1). Similarly, ***smooth*** removes small, often jagged variations in the nodes and arcs, using simple curves instead to improve the appearance of lines and polygon edges. ***Exaggerate*** amplifies a characteristic portion of a map feature when changing scale, such as exaggerating Cape Code in the United States or the Presqu'île de Crozon in France. ***Displace*** adjusts the location of a feature to avoid coalescence with adjacent features. Other operators that alter geometry by dimension include collapse, aggregate, and merge (see Section 2.8).

Resymbolize often is the final step in generalization and describes the visual styling of included map features (see Section 2.9). Symbolization can be as useful as other selection or geometry changes to maintain clarity in the map. Finally, ***enhance*** adds additional symbol embellishments around or withing existing symbols to maintain relationships among symbols (Figure 2.7-2).

Figure 2.7-1: Simplification. Indicator 5.5.1 (2019) on the proportion of women in parliament is mapped in a simplified, angular basemap created by the United Nations to map the SDG indicators at a global scale.



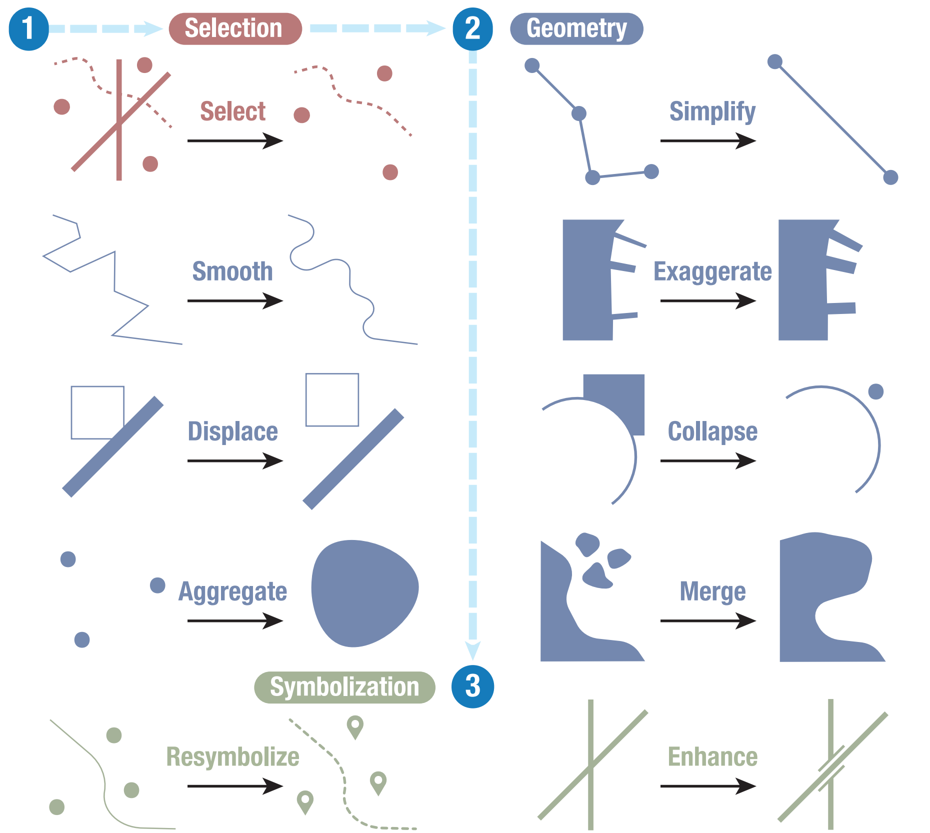


Figure 2.7-2: A typical generalization workflow. Generalization often begins with selection (1), shifts to geometry (2), and concludes with symbolization (3). In practice, generalization is highly iterative and may not include all operators.

2.8 Dimensionality

Dimensionality describes the minimum number of coordinates needed to specify an object's location. In a vector data model, geospatial data can be specified as points (conceptually "zero" dimensions, one XY coordinate), lines (1D, minimum two coordinates to connect the arc), polygons (2D, minimum three coordinates to enclose area), or volumes (3D, with a minimum of four coordinates to enclose the volume) (see Section 1.3). Maps often contain a mixture of features at multiple dimensions (**Figure 2.8-1**).

In the map shown in the bottom-right of **Figure 2.8-1**, the buildings are resized based on a height classification, an individual level attribute of the building. Such statistical use of the third dimension sometimes is described as "2.5D" because it only depicts the top surface of the volume in a static map rather than complete 3D information within the volume. The third dimension also can be used to express temporal data (see Section 3.9).

Consideration of dimensionality is important during generalization, as the same map features may be represented at different dimensionalities to reduce visual complexity when moving from larger to smaller cartographic scales (see **Figure 2.7-1**). ***Collapse*** describes a decrease of dimensionality, such as replacement with a city boundary with a single point at smaller scales. ***Aggregate*** describes an increase in dimensionality, such as enumeration of individual people into a single administrative polygon. Finally, ***merge*** describes a combination of many features into one feature while maintaining dimensionality, such as merging individual countries into larger M49 regions.

Dimensionality is important to thematic mapping (see Section 3.1), as humans perceive lines, polygons, and volumes differently when encoding attribute or temporal information (**Figure 2.8-2**). Lines symbols (1D), such as proportional bars, require visual estimation in a single direction and are largely reliable when used to encode numerical data. However, areal proportional symbols (2D) require estimation in two directions, producing a systematic underestimation as polygon sizes grow larger that can be mitigated through perceptual scaling (see Section 3.4). Underestimation of volumes (3D) is even more severe, and 3D representations usually require interactivity (see Section 4.3).

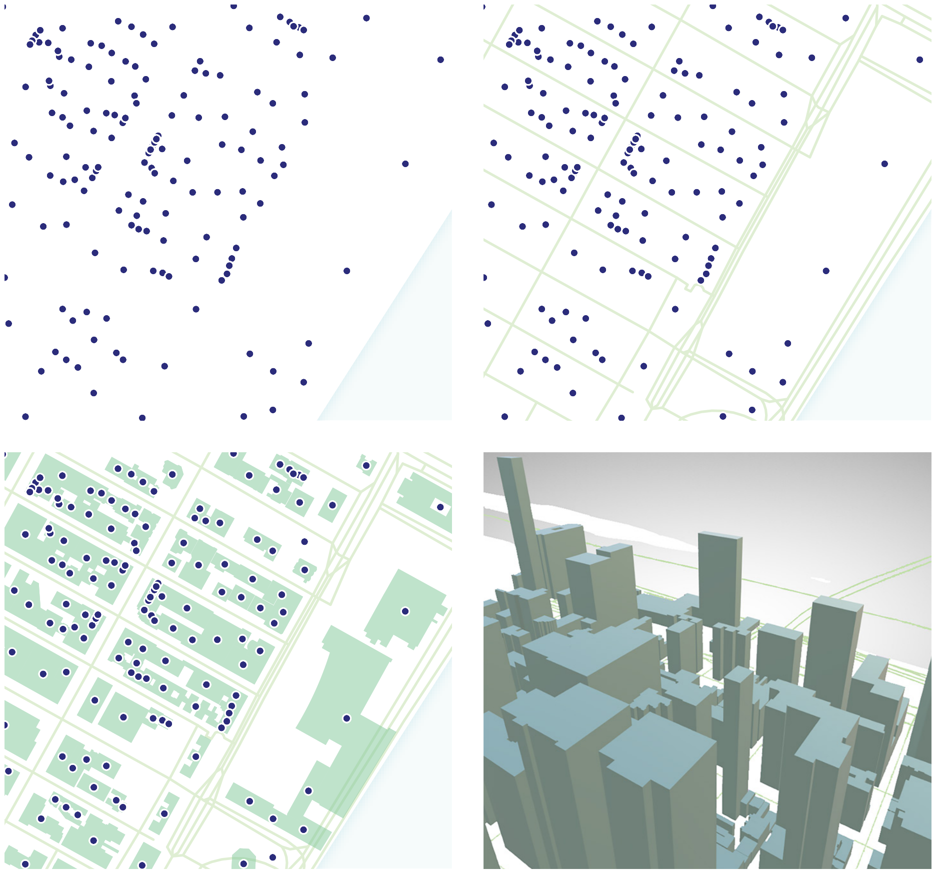
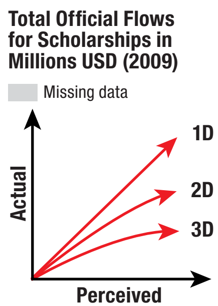


Figure 2.8-1: Symbol dimensionality. The series of figures builds up the **Figure 1.2-2** reference map showing the United Nations headquarters. **Top-left:** Address location points (0D). **Top-right:** Street centre lines (1D). **Bottom-left:** Building footprints polygons (2D). **Bottom-right:** Change to an oblique perspective to depict building heights (2.5D).



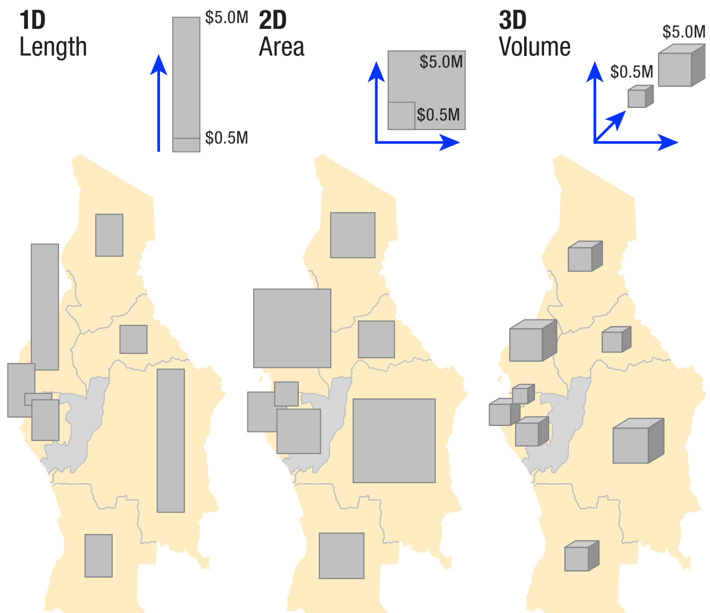


Figure 2.8-2: Perceptual effects on symbol dimensionality. Indicator 4.b.1 (2009) on total official flows for scholarships in Middle Africa is represented as proportional symbol maps by three dimensions. The maps depict the same data, but areas and volumes are perceptually scaled to account for underestimation.

2.9 Symbolization & the Visual Variables

Symbolization describes the graphic encoding of data in a map or diagram. As cartography is a visual language, symbols are the words that cartographers employ to give meaning to the points, lines, and polygons depicted in the map. Far from arbitrary, cartographers choose symbols thoughtfully based on the limits of visual perception, metaphors drawing on cultural associations and practices, and established map design conventions.

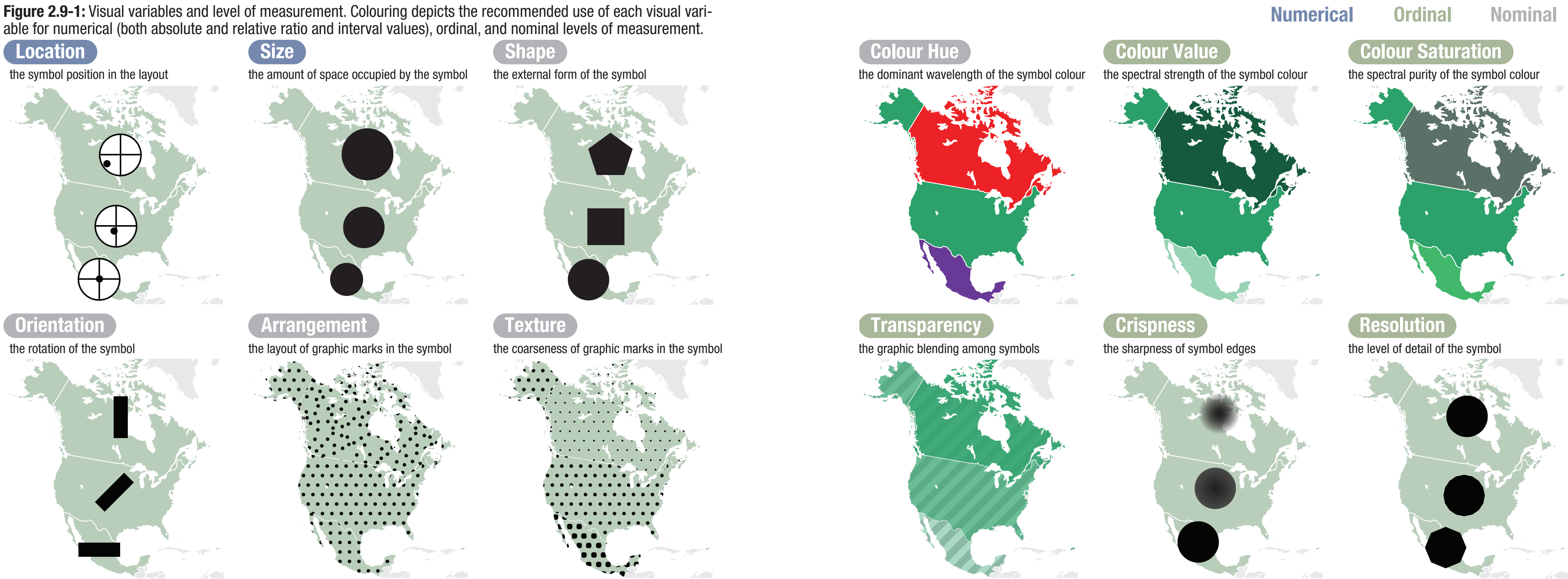
Importantly, symbol design options are limited. The ***visual variables*** describe the ways that a symbol can be modified to convey information. Visual variables include location (logically used to encode the location component of geospatial data in maps), size, shape, orientation, arrangement, texture, colour hue, colour value, colour saturation, transparency, crispness, and resolution (Figure 2.9-1). All map symbols are derived from these basic building blocks or representation primitives.

If symbols are the words of the visual language, then the visual variables inform its syntax. Some visual variables imply an order based on the way they are seen by the eye such as small versus large (size) or light versus dark (colour value). This causes some symbol variations to rise to figure in the visual hierarchy (see Section 2.13). Other visual variables do not imply an order such as circle versus square (shape) or blue versus green (colour hue). Cartographers use this perceptual basis to relate different visual variables to different levels of measurement when mapping attribute data (see Section 1.4), like the SDG indicators.

Unordered visual variables such as shape, orientation, arrangement, texture, and colour hue are recommended for indicators that are collected at a nominal level of measurement. ***Ordered visual variables*** such as colour value, colour saturation, transparency, crispness, and resolution are recommended for encoding indicators that are collected at an ordinal level of measurement. Finally, besides location, the only ***quantitative visual variable*** is size, which is recommended for encoding numerical information at a ratio or interval level of measurement.

Some unordered visual variables, like orientation and texture, may be used for ordinal-level data depending on symbol design and the number of classes. Ordered visual variables can be used for numerical data if transformed into an ordinal set of classes (see Section 1.7), a common solution for many thematic map types (see Section 3.1).

Figure 2.9-1: Visual variables and level of measurement. Colouring depicts the recommended use of each visual variable for numerical (both absolute and relative ratio and interval values), ordinal, and nominal levels of measurement.



2.10 Colour

Colour describes the portion of the electromagnetic spectrum perceived by the eye, also called the visual spectrum. Colour is popularly referenced by the rainbow or ***spectral*** scheme captured in the ROYG(C)BIV acronym: *R*ed, *O*range, *Y*ellow, *G*reen, (*C*yan), *B*lue, *I*ndigo, and *V*iolet.

For symbolization, however, colour comprises three visual variables (see Section 2.9): ***hue*** or the dominant spectral wavelength of the colour (e.g., red versus blue), ***value*** or the spectral strength the colour (e.g., light versus dark), and ***saturation*** or the spectral peakedness of the colour (i.e., bold versus pastel) (**Figure 2.10-1**). Beginning cartographers often overly rely on hue, and it can be easier to establish a clear visual hierarchy by designing in greyscale with only colour value first and then building up hue and saturation to emphasize the most important features (see Section 2.13).

Choosing colours for maps is difficult for a number of reasons. First, the appearance of colour varies if the light is emitted directly from a computer screen or reflected from another light source off a printed page. Accordingly, use the additive ***RGB*** (*R*ed, *G*reen, *B*lue) colour model when designing digital maps that use emitted light and the subtractive ***CMYK*** (*C*yan, *M*agenta, and *Y*ellow, with blac*K* added for richer colour depth in dark mixtures) colour model when designing print maps that reflect light.

Second, visual acuity varies by colour hue, leading to more perceptible variations in blues and reds than yellows and greens. ColorBrewer2.org provides colour schemes that are perceptually scaled, although the appearance of one colour in the map may shift based on surrounding colours due to an effect called ***simultaneous contrast***.

Finally, the perception of colour varies considerably across map users, with roughly five per cent of the global population exhibiting some form of colour-vision deficiency. Further, a decline of visual acuity occurs with age or injury (see Section 4.2). Colour also has highly variable cross-cultural connotations and, thus, may suggest different meanings across Member States.

Three different kinds of ***colour schemes***, or logical sets of colour symbols, are used in this book to map SDG indicators. A ***sequential*** scheme orders colours with an apparent increase from low-to-high, making it useful for repre-

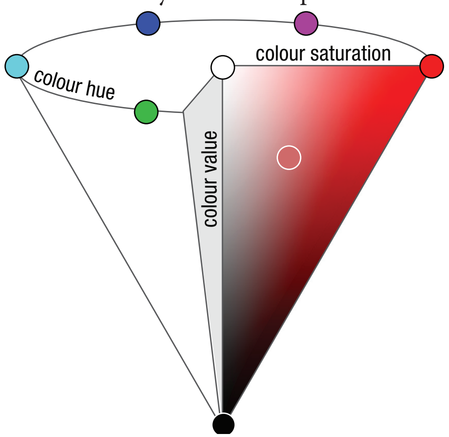


Figure 2.10-1: The HSV colour model. The three visual variables of colour can be modelled as a conic colour space, with hue as a circular continuum, value approaching black at the bottom of the cone point, and saturation moving from spectral pure colour to grey. Graphic design software enables digital translation among HSV, RGB, and CMYK colour models, but may result in unavailabe, "out-of-gamut" colour translations.

Figure 2.10-2: Sequential colour scheme. Indicator 8.1.1 (2016) on the annual growth rate of real GDP per capita is mapped using a sequential colour scheme. Use a sequential colour scheme for ordinal data or classed numerical data with an apparent increase from low-to-high in one direction.

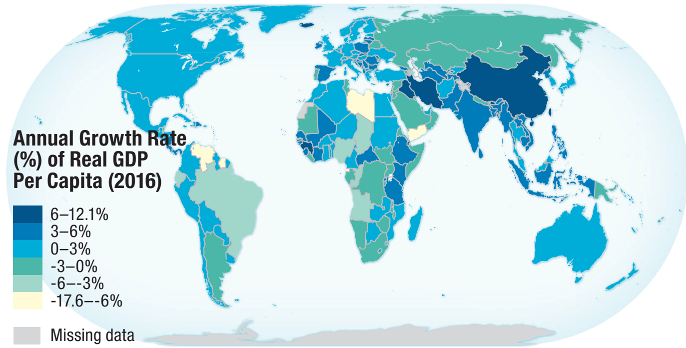


Figure 2.10-3: Diverging colour scheme. Indicator 8.1.1 (2016) is remapped with a diverging colour scheme using zero per cent change as the critical midpoint. Use a diverging colour scheme for ordinal data or classed numerical data with an increase in two directions away from a critical value (e.g., zero, the mean or median).

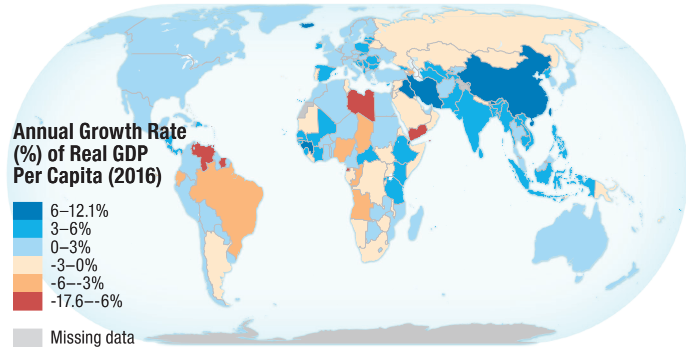
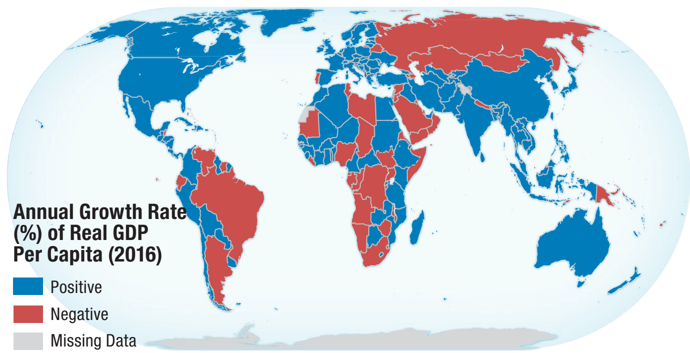


Figure 2.10-4: Qualitative colour scheme. Indicator 8.1.1 (2016) is transformed to a binary positive or negative change. Use a qualitative colour scheme for categorical data with no apparent ranked order (e.g., mode). Do not use a spectral colour scheme based only on colour hues to map ordinal or numerical data, unless removing greens.



senting ordinal data or classed numerical data (**Figure 2.10-2**). A ***diverging*** scheme combines two sequential schemes to create an apparent increase in two directions, making it useful for ordinal data or classed numerical data with a critical midpoint value (**Figure 2.10-3**). Finally, a ***qualitative*** scheme has no apparent order and is useful for nominal data (**Figure 2.10-4**). These three colour schemes can be applied to point, line, and, most commonly, polygon features.

2.11 Typography

Typography describes the styling and placement of text. In cartography, ***labelling*** (i.e., map text) is the primary method for adding detail back into the map after generalization (see Section 2.7), and it can make or break the effectiveness of map design.

Thematic maps, like those depicting the SDG indicators, often have fewer labels than general reference maps, which are purposefully comprehensive and dense in labelling (see Section 3.1). However, labelling and other annotation remains important for thematic mapping to accent notable patterns, trends, and anomalies.

The goal with both label styling and placement is to maintain a clear ***graphic association*** between label and feature without ***overprinting*** labels on features or labels on labels. Label styling also evokes congruency with the labeled feature, including the typeface (e.g., serif versus sans serif), style (e.g., roman, italic, bold), size (8pt versus 10pt), case (upper versus lower), colour (see Section 2.10), and character spacing (also called tracking).

Serif typefaces are recommended for natural features (e.g., deserts, mountain ranges, water bodies) as the serif embellishments mimicking handwriting evoke the uneven edges of the natural environment. ***Sans serif*** typefaces are recommended for cultural features (e.g., buildings, roads, political units) as the clean lines evoke the built environment.

Label styling often is used to differentiate categories of map features and reinforce the overall visual hierarchy (see Section 2.13). Use italics and colour hue for representing nominal differences at the same visual level and use bolding, colour value, and type size to depict ordinal differences within the visual hierarchy (see Section 2.13). Do not use text to represent numerical differences, as the length of the label conflates with the type size, leading to an inaccurate estimation.

Label placement is based on the dimensionality of the labeled feature (see Section 2.8). **Figure 2.11-1** and **2.11-2** illustrate suboptimal versus improved type styling and placement, respectively.

For point labels, label horizontally or curved with the graticule, with the label slightly misaligned above or below the point to avoid the reading of the point feature as a text character. Label microstates, island nations, and other small countries by area like point features when at smaller cartographic scales.

For line labels, label the section of the line where it is most horizontal and bends the least, using a gentle curve placed above the line. Line labels are rare when mapping SDG indicators but may be useful as map context for development along major river systems, roadways, etc.

For polygon labels, label horizontally or as a curve along the major axis of the polygon, changing the spacing between characters to fill the available space. Avoid changing the size of the label based on the available space as this biases the eye towards these larger regions.

Figure 2.11-1: Autolabelling in mapping software. Labels lose graphic association and overprint symbols.

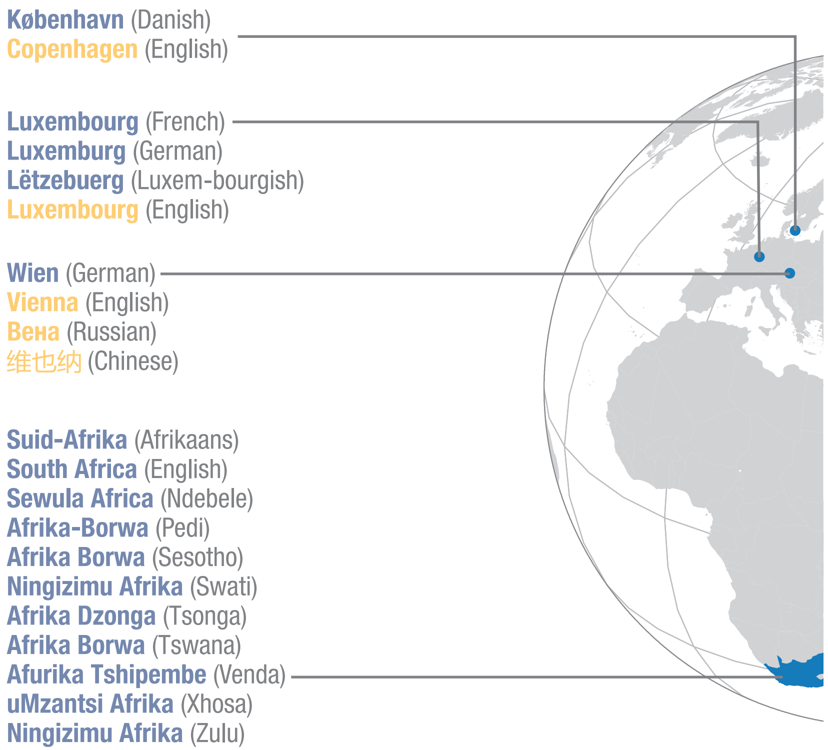
Figure 2.11-2: Improved labelling. Labels now promote graphic association and reinforce visual hierarchy.

2.12 Toponymy

Toponymy is the study of place names, their origins, meanings, and uses. ***Toponyms***, or geographic place names, reflect relationships among people and cultures across geography and history. A toponym may originate from within the named place (an ***endonym***) or from outside of the named place (an ***exonym***), with endonyms requiring ***transliteration*** to alternative languages and alphabets for global identification (**Figure 2.12-1**). Accordingly, there may be multiple accepted names for a single place, and Indigenous groups and local communities may contest exonyms derived from colonial, racist, or otherwise culturally insensitive geopolitical and historical practices.

The United Nations leads national and international standardization and management of geographic names. Its mission on toponymy was articulated in 1959 by United Nations Economic and Social Council resolution 715A (XXVII), which established the ***United Nations Group of Experts on Geographical Names*** (***UNGEGN***) and led to the first meeting on toponyms in 1960. Today, the UNGEGN assists national place-name efforts—particularly to involve Indigenous groups and local communities in the process—and facilitates discussion of best practices on toponymy. The general recommendation for primary place names is to revert to endonyms over exonyms where possible and to support multiple place names where appropriate.

In cartography, toponyms fill the content of map labels (see **Section 2.11**) and, thus, serve as important reference information for clarifying locations significant to the map subject and purpose. Cartographers need to be aware of the geopolitical and historical implications of using exonyms versus endonyms. However, as cartography is transnational, selection of toponyms should be suitable to its intended audience language while addressing concerns about exonyms from Indigenous groups and local communities. Given that most indicators currently are reported at the country level, geographic names endorsed by the respective national authoritative bodies are recommended for labelling national-level maps.



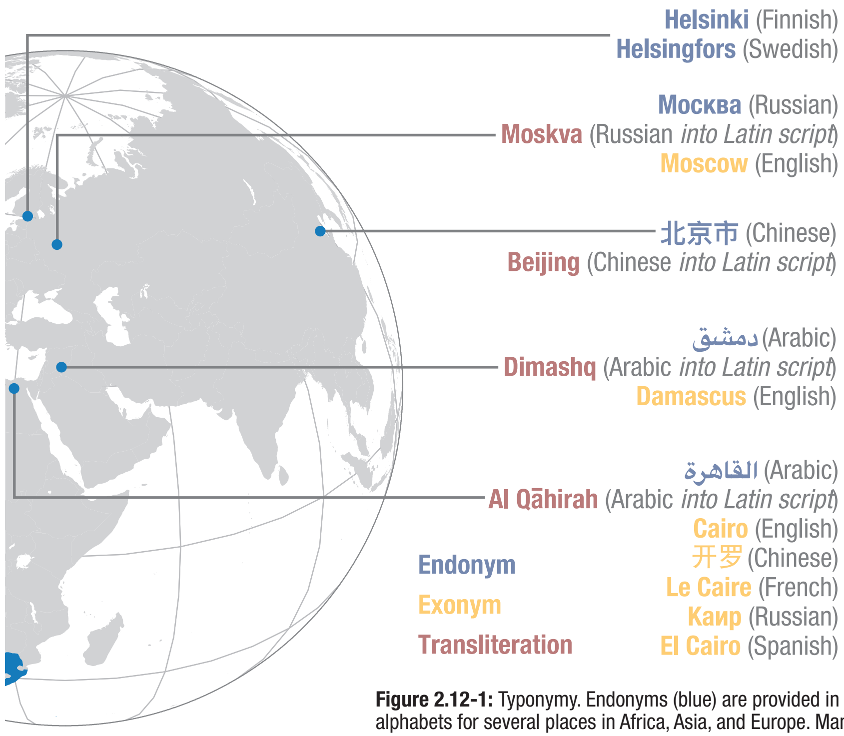


Figure 2.12-1: Typonymy. Endonyms (blue) are provided in local alphabets for several places in Africa, Asia, and Europe. Many places have multiple accepted endonyms. Exonyms (yellow) and transliteration (red) to Latin script are listed beneath each endonym.

2.13 Layout & Visual Hierarchy

The ***layout*** describes the placement of ***map elements*** on the map page or screen, such as the title, legend, indications of scale and north, the map itself, and other text and annotation. The map layout and visual hierarchy strongly influence the order that map elements are read and, therefore, the effectiveness and efficiency in communicating the map subject and purpose. The user should immediately understand what the map is about (external identification realized via the map title) and how the topic is expressed (internal identification via the legend).

In traditional cartographic design, the map is placed as large as possible in the optical centre of the layout to provide as much detail as possible. Other map elements then are placed in the ***negative space*** created by the shape of the mapped area (e.g., to the bottom-left in **Figure 2.13-1**), rather than shrinking or offsetting the map to free space for other elements. Accordingly, the ***aspect ratio*** (horizontal versus vertical dimensions of the layout) should match the dominant axis of the mapped geography (e.g., portrait for Africa, landscape for Australia).

Managing negative space between map elements results in an imbalanced versus balanced layout (**Figure 2.13-1**). Typically, neatlines that separate map elements into different frames are not needed if the amount of negative space between map elements remains consistent, resulting in a more aesthetically-pleasing, fluid layout. New interactive or storytelling techniques where the “page” is a “screen” break from traditional map layouts in creative ways, placing map elements and additional content behind interactive pop-ups (see **Section 4.4**) or layout of

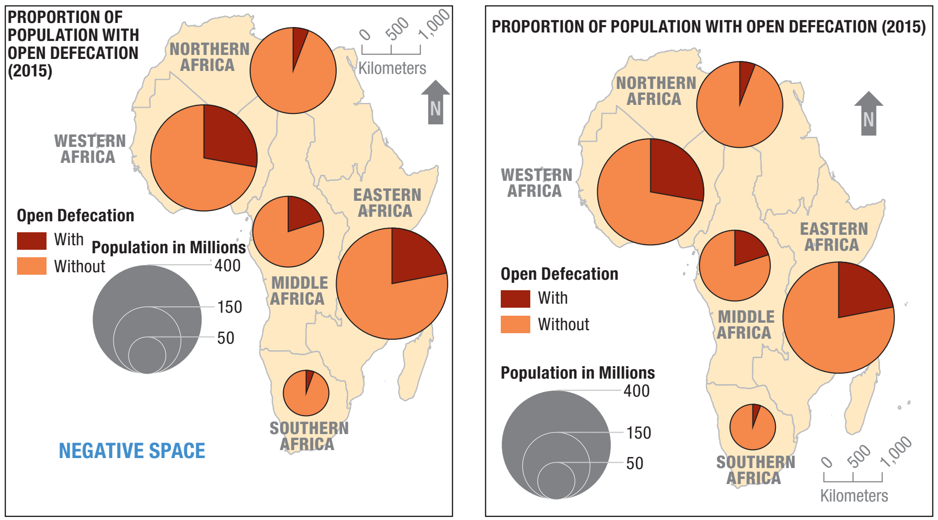


Figure 2.13-1: Map layout. **Left:** Indicator 6.2.1 (2015) on the proportion of population with open defecation is mapped with an imbalance layout, compressed at the top and right creating a large negative space at the bottom. **Right:** A balanced, fluid layout making use of the negative space in the bottom-left created by the shape of Africa.

the map elements in a scrollable webpage for a linear narrative (see **Section 4.7**).

In contrast, the ***visual hierarchy*** describes the order that map elements are perceived visually. Maps are not read linearly from top to bottom like text, and good cartographic design draws the eye to information on the map that is most important. Specifically, the most important map features should rise to the foreground, described as the ***figure*** in the visual hierarchy, while increasingly less important map features should recede to the background, or ***ground***. Thus, it is useful first to rank all map features and map elements into an intellectual hierarchy and then establish figure-ground relationships among map features and elements based on the intellectual hierarchy (**Figure 2.13-2**).

For the SDGs, the visual importance of different locations is based on the indicator data itself and, thus, different enumeration units will be more or less important depending on a specific indicator and time period. The visual variables (see **Section 2.9**) match visual weight of a symbol to attribute data, with variations in each visual variable resulting in a data-driven visual hierarchy within the map (e.g., larger sizes rise to figure, desaturated colours recede to ground). While all visual variables have at least subtle figure-ground relationships, those recommended for ordinal and numerical levels of measurement result in strong figure-ground relationships and, thus, a clear visual hierarchy within the map. Labels and annotations often are added at the top of the visual hierarchy to further accent the most important features in the map.

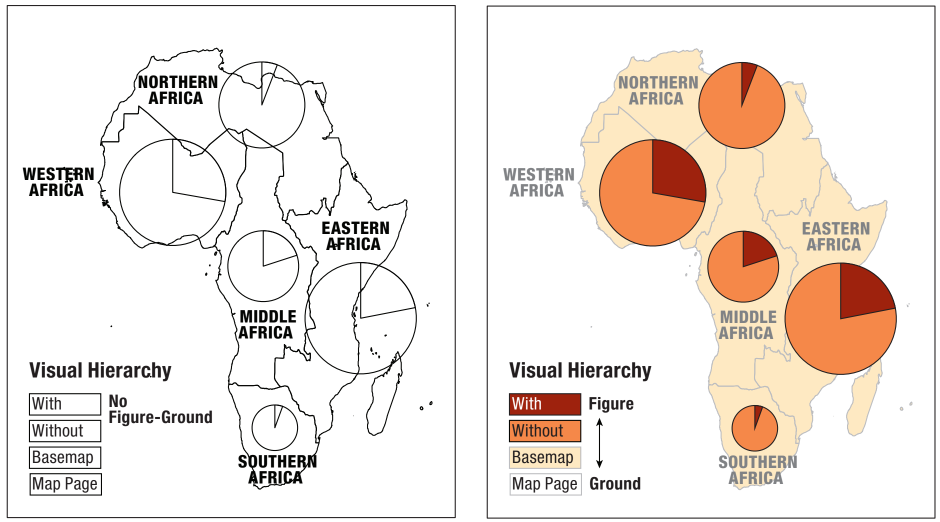


Figure 2.13-2: Visual hierarchy. **Left:** Indicator 6.2.1 (2015) on the proportion of population with open defecation is mapped with a flat visual hierarchy, making it difficult to visually interpret the proportional pie chart symbol. **Right:** Use of the visual variables to establish a visual hierarchy that matches the map’s intellectual hierarchy.

2.14 Visual Art & Visual Style

Cartography often is described as both an art and a science. As an intergovernmental organization, the United Nations serves global *humanitarian* efforts, and its treatment of map design as an artistic process enables new ways to *humanize* the otherwise abstract statistical SDG indicator data.

As ***visual art***, maps help us share our experiences of the world, promote empathy and compassion about uneven social and environmental conditions, and inform policy and politics for forging a sustainable future. As ***visual culture***, maps reflect our interests and values, make us to confront our failures and prejudices, and reveal potential alternatives and opportunities.

The potential for artistic perspectives on cartography are numerous and ever expanding. One important way that artist elements enter every map design is through its ***visual style***, or a cohesive set of design characteristics and qualities that reinforce rather than undermine the purpose of the map.

A visual style can be deconstructed into its elemental forms, colours, typefaces, and textures (**Figure 2.14-1**). ***Form*** describes the variable aspects of the geospatial linework, including its generalized detail (see Section 2.7) and line weights, cap and joint styles, and tapering. Colour and typography—defined in Section 2.10 and Section 2.11 respectively—greatly influence the map's visual style. Both colour and typography evoke strong but different connotations cross culturally. Texture, a visual variable (see Section 2.9), describes the additional pattern fills and overlays that add visual complexity and often suggest a physical materiality or historical pastiche.

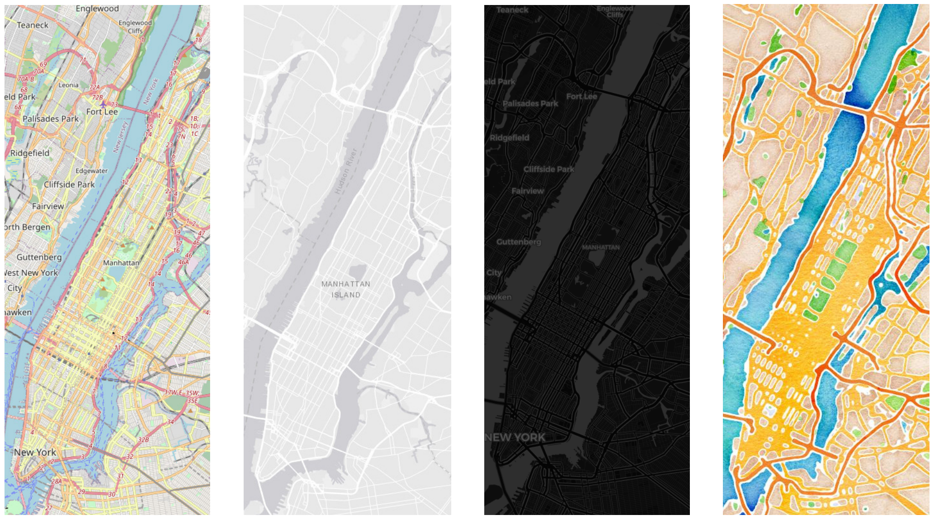


Figure 2.14-1: Visual styles in four web basemaps. **Left:** OpenStreetMap Mapnik uses detailed linework, complex colours and textures, and dense type, activating the audience and producing a sense of accuracy and trustworthiness in the basemap. **Left-centre:** Esri World Light Gray Canvas uses simplified linework and visual hierarchy along with muted colours, textures, and labels to deactivate the audience, making it a good basemap when additional data overlays should rise to figure (see Section 4.6). **Right-centre:** CARTO Dark Matter similarly uses simplified linework and sparse type and textures but with a darkened colour palette, setting an ominous, tense tone in the map. **Right:** Stamen Watercolor includes whimsical linework, bright colours with no type, and textures mimicking the spread of watercolours over paper, evoking a pleasant almost serene sense of beauty with the map.

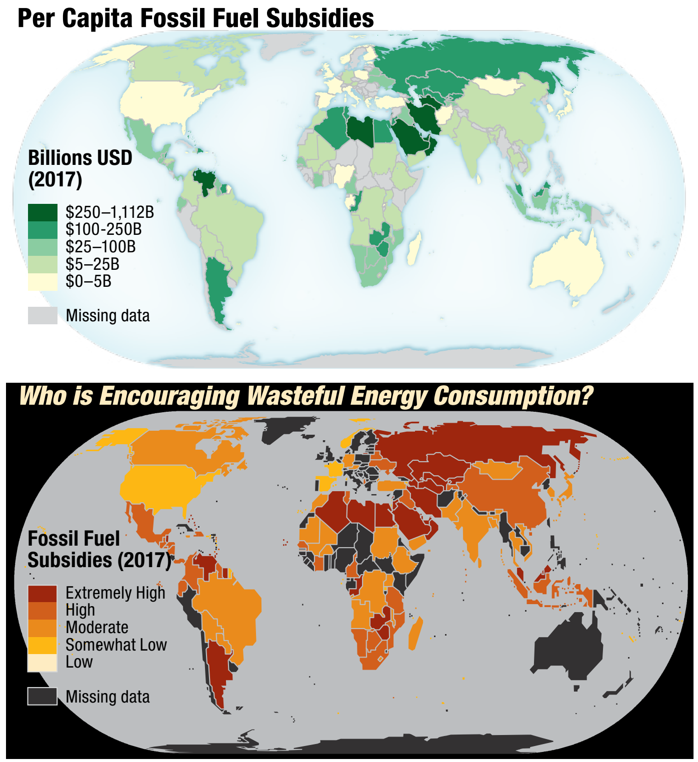


Figure 2.14-2: Visual styles and emotion. Indicator 12.c.1 (2017) on per capita fossil fuel subsidies in USD is mapped in two different visual styles. **Top:** The minimalist, authoritative style includes detailed linework and a soft colour palette. The map uses an arithmetic classification to emphasize low values in the left-skewed data distribution. Such a minimalist style likely evokes a pleasant, but deactivated emotional experience. **Bottom:** The alternative, creative style includes angular linework and bold colours against a black background, with the title framing the map purpose. Ordinal data are mapped with a quantile classification, placing more countries into the higher classes. Such a sensationalist style likely evokes an activated, unpleasant emotional experience, which may or may not be appropriate for the mapping context.

The visual style of the map has a major impact on the audience's emotional experience: both setting the mood as a pleasant or unpleasant topic while also engaging or boring the reader. Understanding the relationship between style and emotion helps cartographers identify a visual style that matches the gravity of the mapped phenomena while avoiding blatant map propaganda. A minimalist, authoritative style often is applied when mapping the SDG indicators, such as many of the maps in this book (**Figure 2.14-2**, top), to assert neutrality and suggest data accuracy. However, no map design is perfect nor free from subjectivity (see Section 2.3), and alternative, creative visual styles may better promote awareness, generate dialogue, and stimulate action (**Figure 2.14-2**, bottom).

A visual style that works well in one mapping context may be illegible, misleading, or even harmful in others.

2.15 Missing Data & Representing Uncertainty

Missing data describes the absence of an attribute value for a particular location and year. For the SDG indicators, many indicators are not yet collected by all Member States or only have been collected since the 2015 launch of the SDGs. Alternatively, indicator data may be missing if there are privacy concerns or if there is no established collection methodology or standards. The three tiers introduced in [Section 1.6](#) classify the indicators based on their data completeness (see **Figure 1.6-1**).

Importantly, "missing" data is not synonymous with a "zero" data value, as ***zero*** indicates the absence of the phenomenon within that enumeration unit, not the absence of data on the phenomenon. Missing data and zero should be symbolized differently in the map (**Figure 2.15-1**).

Data from prior years can be used to reduce the number of enumeration units with missing data, improving completeness at the cost of hindering consistency and currency. A special symbol or footnote should be included to denote locations mapped with older data.

Missing data is one form of ***uncertainty***, or the gap between the reality represented in the map and the understanding the audience derives from the map. All geospatial data contain multiple types of uncertainty that impact its quality and fitness of use for mapping.

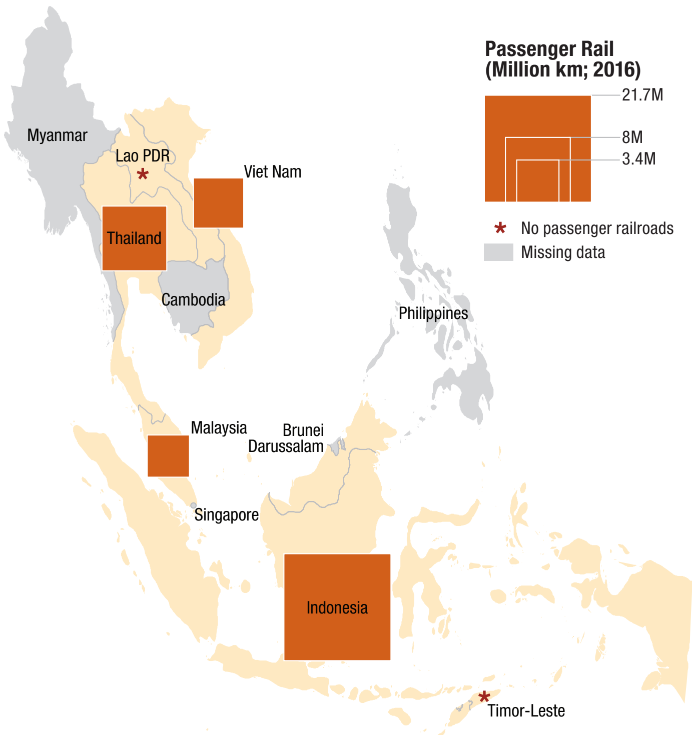
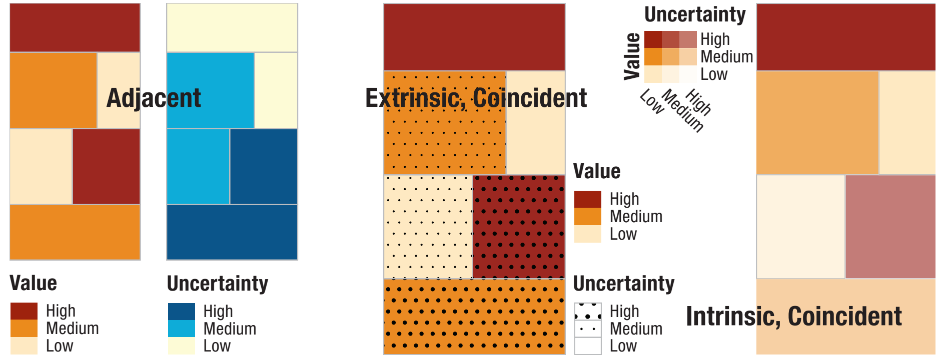


Figure 2.15-1: Missing data versus zero. Indicator 9.1.2 (2016) on passenger rail volume includes both missing data and zero values. **Figure 1.7-2** is remapped for South-Eastern Asia M49 sub-region using proportional symbols. Laos and Timor-Leste do not have railroads and, thus, have zero rail passengers, which are represented on the map with an asterisk rather than a proportional symbol. Brunei, Cambodia, Myanmar, Philippines, and Singapore have missing data for 2016 and instead are represented with a desaturated grey colour, the solution for missing data used throughout this textbook.



2.15-2: Representing uncertainty on maps. **Left:** Adjacent maps. **Centre:** An extrinsic, coincident map using overlaid textures for uncertainty. **Right:** An intrinsic, coincident map desaturating colour to represent uncertainty.

Common uncertainties in geospatial data include ***accuracy***, or the correctness of the data, and ***precision***, or the exactness of the data. Values only are integrated into an indicator dataset when they meet accuracy and precision standards.

Other uncertainties impact the ***trustworthiness*** of the data, which captures additional issues regarding confidence in the data. Trustworthiness is affected by the aforementioned data ***completeness*** (the amount of missing data values), ***consistency*** (the uniformity in data collection), and ***currency*** (the age of the data). Trustworthiness also is affected by the data ***credibility*** (the data source), ***lineage*** (the data transformation process; see [Section 1.7](#)), ***subjectivity*** (the degree of human interpretation during the data transformation process), and ***interrelatedness*** (the dependence of the data on the quality of other datasets).

Visualizing uncertainty gives the audience an understanding of where data are imperfect and, thus, that the map is not absolute truth. **Figure 2.15-2** illustrates common solutions for representing uncertainty on maps.

An ***adjacent map***, sometimes called small multiples (see [Section 3.9](#)), represents data and its uncertainty in separate maps. The audience must compare adjacent, smaller maps mentally but can attend to each map individually without the added complexity of a bivariate map (see [Section 3.7](#)).

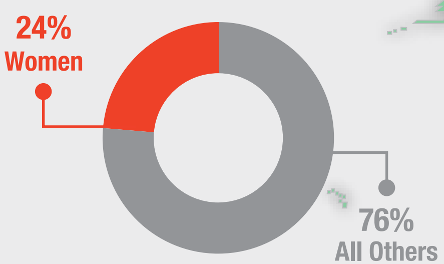
An ***extrinsic*** (different layers) and ***coincident*** (same map) ***map*** represents uncertainty atop the original map as a second thematic layer. Extrinsic, coincident maps focus attention to areas that are *uncertain*, given the overprinting of additional symbols or textures for uncertainty.

An ***intrinsic*** (same layer) and ***coincident map*** represents uncertainty by modifying the symbolization used for the data itself. Intrinsic, coincident maps focus attention to areas that are *certain* by giving reduced visual weight to symbols that are uncertain. Visual variables for intrinsic uncertainty representation include saturation, value, crispness, resolution, and transparency (see [Section 2.9](#)).

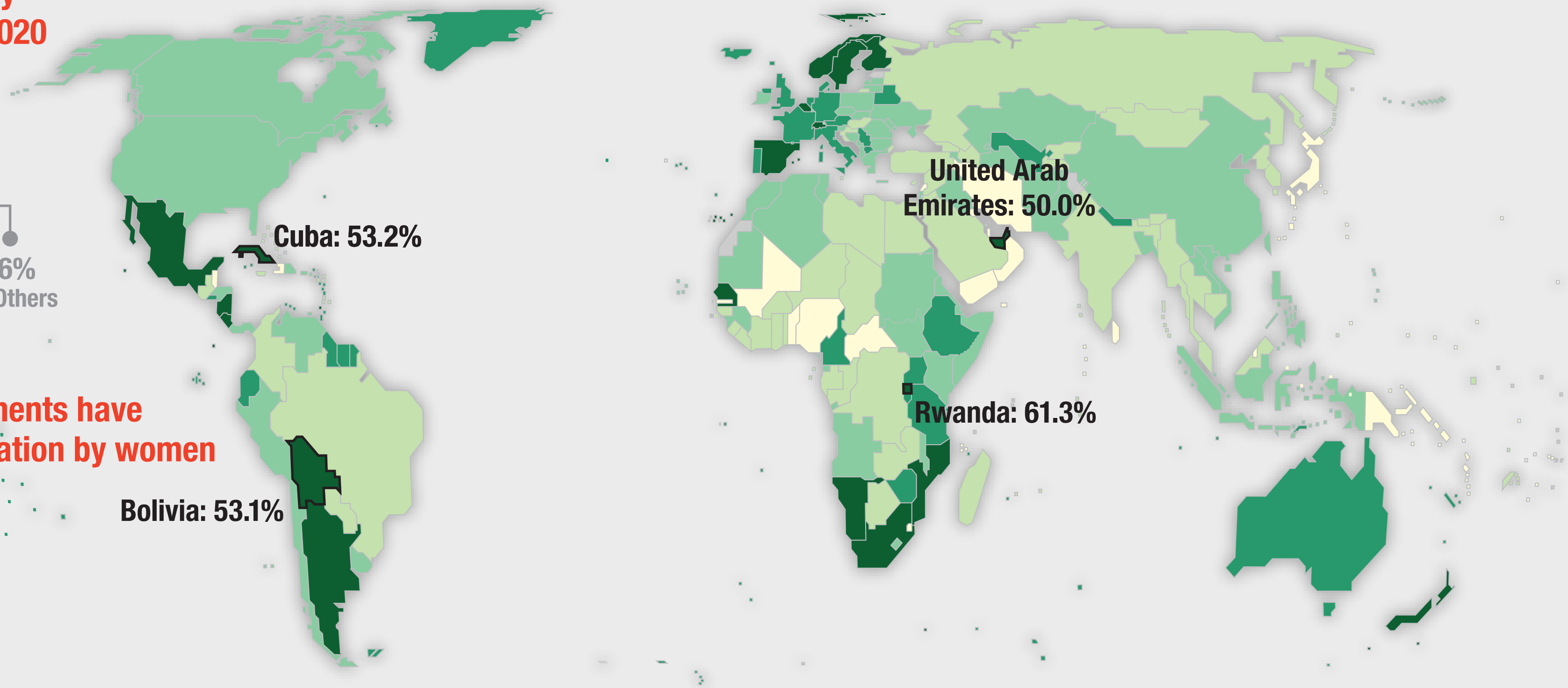
GOAL 5: ACHIEVE GENDER EQUALITY AND EMPOWER ALL WOMEN AND GIRLS

SDG Target 5.5
Ensure women's full and effective participation and equal opportunities for leadership at all levels of decision-making

▶ Only 24% of parliamentary leaders were women in 2020



▶ Only four national parliaments have 50% or greater representation by women



▲ The map depicts Indicator 1.5.1 (2020) on the proportion of seats held by women in national parliaments as a choropleth map. Countries for the choropleth map are highly generalized to show only the overall thematic patterns, simplifying the message. This style also increases the visual weight of smaller nations. UN Women promotes this basemap for its publication on "Women in Politics."

Although simplified, the map remains projected in the Eckert IV equivalent projection used throughout the book, allowing for comparison of areas in the choropleth. The choropleth map uses an equal interval classification for the uniform attribute distribution and a sequential colour scheme that crosses yellow to green colour hues but primarily relies on the ordered visual variable colour value.

◀ Wide view of the opening meeting of the sixty-fourth session of the Commission on the Status of Women (CSW). Member States adopted a political declaration in which they pledged to step up action to fully implement the landmark Beijing Declaration and Platform for Action on gender equality, agreed to 25 years ago. (Source: UN Photo/Loey Felipe, 2020)

5 GENDER EQUALITY

SECTION 3: MAPS & DIAGRAMS

3.1 Thematic Maps

A ***thematic map*** depicts the variation of one or sometimes several (see Section 3.7) geographic phenomena, mapping spatial and attribute information together. Meeting the SDGs requires thematic mapping of indicator data. Thematic maps enable geographic imagination and spatial thinking, and often represent abstract or statistical concepts that cannot be observed directly.

Thematic maps primarily depict attribute information that is enumerated within polygonal geographic units (see Section 1.4). Enumerated attributes typically are mapped at an ordinal or numerical level of measurement, as enumeration results in quantitative counts or frequencies. Nominal differences can be represented in thematic maps, such as the mode or a binary value, resulting in a ***nominal map*** (see Section 3.2).

Each thematic map type symbolizes attribute data using a different visual variable (see Section 2.9). A ***choropleth map*** (see Section 3.3) shades enumeration units by their attribute values, primarily relying on colour value. A ***proportional symbol map*** (see Section

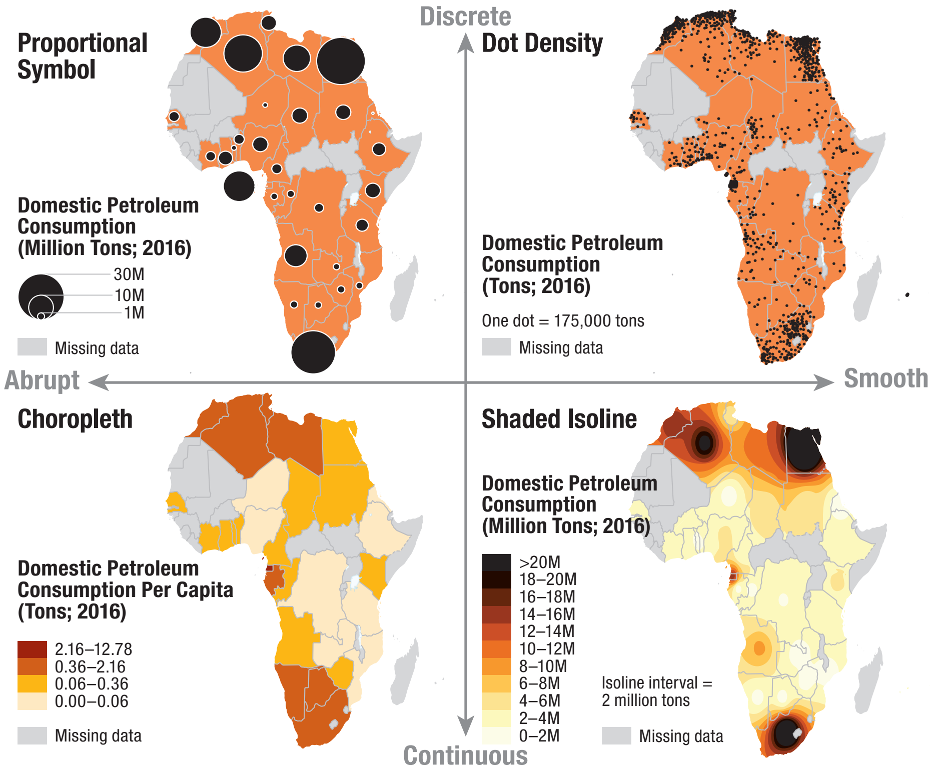


Figure 3.1-1: Thematic map types. The four maps depict Indicator 12.2.2 (2016) on domestic petroleum consumption. **Top-left:** Proportional Symbol. **Top-right:** Dot density. **Bottom-left:** Choropleth. **Bottom-right:** Shaded isoline.

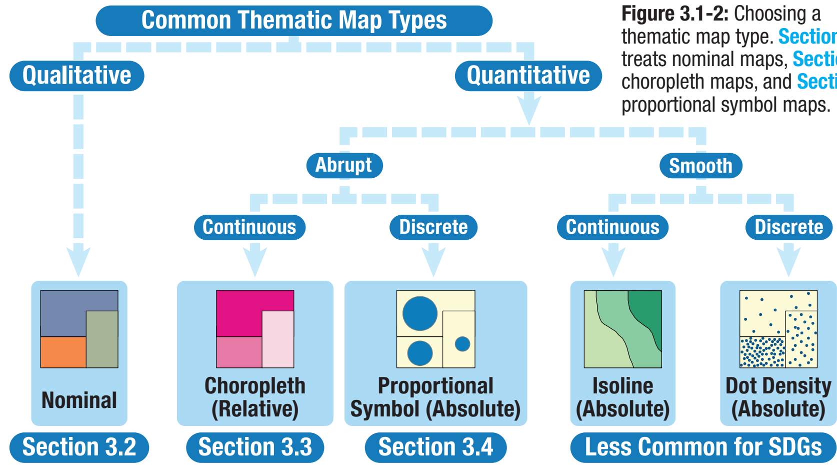


Figure 3.1-2: Choosing a thematic map type. Section 3.2 treats nominal maps, Section 3.3 choropleth maps, and Section 3.4 proportional symbol maps.

3.4) uses the visual variable size to scale point symbols by their attribute values. A ***dot density map*** (different from dot maps; see Section 3.2) uses the composite visual variable ***numerousness*** (arrangement combined with size) to adjust the density of dots placed within enumeration units by their attribute values. Finally, an ***isoline map*** interpolates between sampled attribute values, using the visual variable location to represent the interpolated attribute gradient as a new geospatial data layer.

Each thematic map type also carries a different ***visual metaphor***, or a visual representation that evokes characteristics of the mapped phenomenon not explicitly expressed within the data. Different visual metaphors may lead to different framings of and conclusions about the same attribute data. Visual metaphors are particularly pertinent when mapping enumerated data like the SDG indicators because information about how the phenomenon exists within space (discrete versus continuous) and varies across space (abruptly versus smoothly) is lost during enumeration (Figure 3.1-1). Choropleth maps evoke a metaphor of continuous and abrupt phenomena, such as governmental activities, policies, and regulations fixed to political jurisdictions (i.e., enumeration units). Proportional symbol maps evoke a discrete and abrupt metaphor, suggesting economic sites of production and distribution like mines, factories, offices, and stores. Dot density maps evoke a discrete and smooth metaphor, suggesting the individual bodies of human and social phenomena. Isoline maps evoke a continuous and smooth metaphor, suggesting environmental or geophysical phenomena.

Figure 3.1-2 provides guidance for choosing a thematic map type. Dot density and isoline maps are used infrequently for the national-level indicator datasets given difficulty in reliably depicting smoothly changing patterns at coarser levels of enumeration.

3.2 Nominal Maps

A nominal map depicts categorical data (see Section 3.1) and, thus, relies on unordered visual variables (see Section 2.9). Nominal maps represent both individual-level and enumerated data (see Section 1.4) as well as point, line, and polygon dimensionalities (see Section 2.8). While the SDGs mostly include quantitative data, several indicators and other contextual United Nations designations (e.g., the M49 codes and SDG regional groups; see Section 1.3). require nominal mapping. Further, all numerical SDG indicators can be transformed to nominal values to simplify the map's message (see Section 1.7).

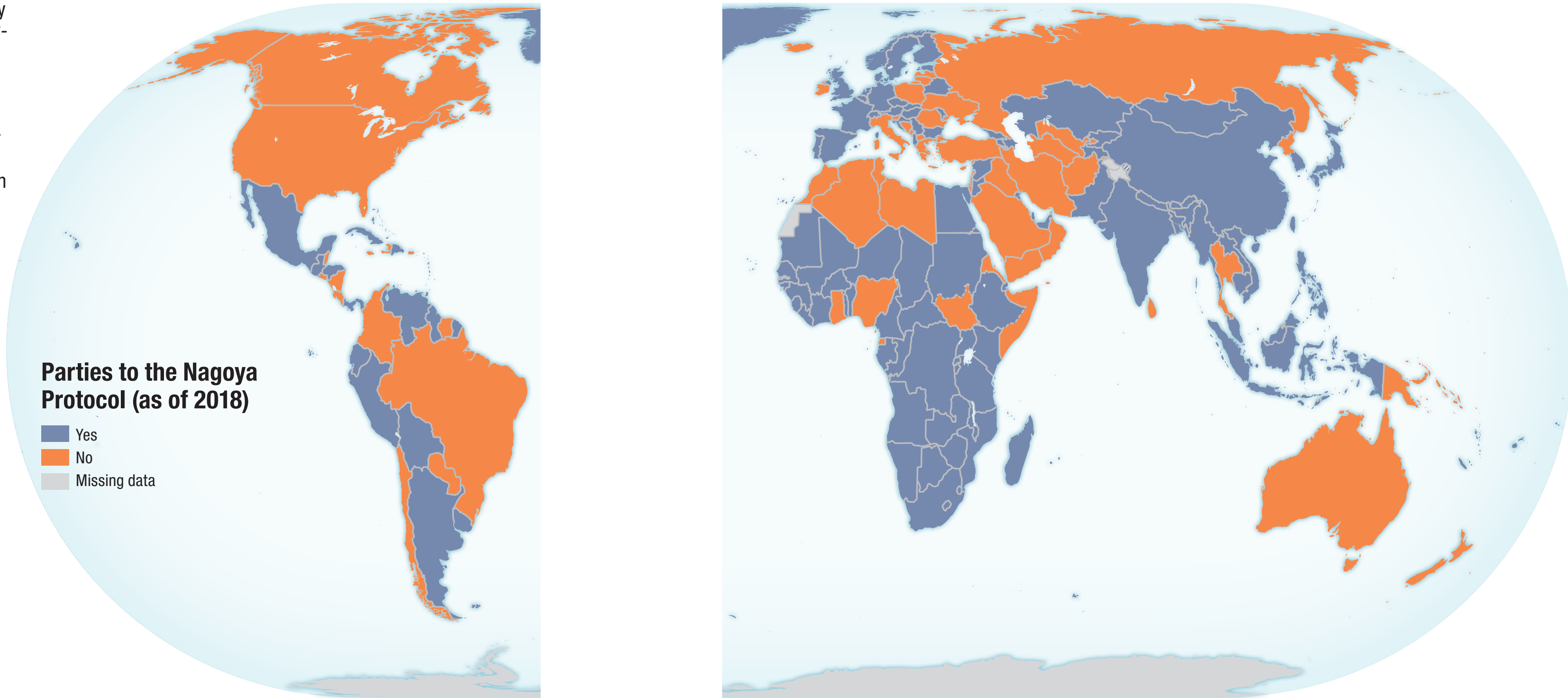
A nominal map of points results in a ***dot map***, with each dot corresponding to a single place. Dot maps use colour hue or shape to represent nominal data at individual-level locations. Accordingly, dot maps differ from dot density maps (see Section 3.1), as the latter randomly places dots to build an apparent density with each dot representing a numerical rather than nominal value.

Dot maps often employ complex ***icons*** that resemble prominent visual characteristics associated with the mapped category such as a book icon for "Library" or a tree icon for "Park". The colour hue or outer frame shape of the icon can be used to represent additional nominal categories (e.g., combining library and school icons into an "Education" category). Icons have variable cross-cultural meanings, and stereotypes should be avoided when selecting icons for dot maps.

Nominal maps of lines and polygons primarily use the visual variable colour hue and qualitative colour schemes (see Section 2.10). A thematic map of linear features is called a ***flow map*** and symbolizes attribute relationships between places rather than attribute values at places. Flow maps also can encode quantitative information using colour value or size (i.e., line thickness).

There are two applications of nominal maps for SDG indicators. First, a nominal map can depict the ***mode***, or the most common value found within a polygonal enumeration unit. The mode is an alternative measure of central tendency to the ***mean*** (sum of all values divided by the total observations) and ***median*** (the middle observation when ordered) useful for normalizing absolute values in choropleth maps. Second, several of the SDG indicators are reported as a ***binary*** presence/absence or yes/no (Figure 3.2-1). Nominal maps of binary indicators can depart from a qualitative colour scheme to emphasize one category over the other.

Figure 3.2-1: Binary nominal map. The binary nominal map depicts Indicator 15.6.1 identifying countries that have adopted (as of 2018) legislative, administrative, and policy frameworks to ensure fair and equitable sharing of benefits of biological diversity, as outlined in the Nagoya Protocol. A more saturated colour is used for the "No" category, emphasizing countries that have yet to ratify the protocol in the binary nominal map.



3.3 Choropleth Maps

A choropleth map is a thematic map that shades enumeration units by their attribute values (see Section 3.1). Choropleth maps represent quantitative, enumerated data (see Section 1.7) and rely on the visual variable colour value to create a visual order from light-to-dark colours or from dark-to-light colours when using a dark background (see Section 2.9). They also employ colour hue and colour saturation in multi-hued spectral schemes and all diverging schemes (see Section 2.10). Choropleth maps also may vary texture or transparency to represent missing data or other kinds of uncertainties (see Section 2.15).

Choropleth maps commonly are used by national statistic agencies or other authoritative bodies that enumerate data within hierarchical sets of political boundaries. Accordingly, choropleth maps often are the default technique for mapping the SDG indicators. However, these maps evoke a visual metaphor of continuous and abrupt phenomena and, therefore, work best for mapping governmental activities, policies, and regulations fixed to political jurisdictions. Alternative thematic map types, particularly proportional symbol maps (see Section 3.4), might offer a more appropriate metaphor for economic indicators.

Choropleth maps are common in popular media because they are easy to make. General audiences also are relatively more familiar with them, improving consistency in their interpretation. However, choropleth maps have several limitations requiring unique design solutions.

First, they suffer from the modifiable areal unit problem (see Section 1.8), arguably more so than other thematic maps because the colour symbolization is applied to the entire enumeration unit itself rather than using additional symbols atop or across the enumeration unit (as with proportional symbol, dot density, and isoline maps). Therefore, absolute values must be normalized into relative values on choropleth maps to ensure comparability across enumeration units of different size and shape. Relatedly, choropleth maps also require an equivalent projection (see Section 2.4) to preserve the relative amounts of colours across the map. Thus, a proportional symbol map is a better choice for online mapping of the indicators if limited to the non-equivalent Web Mercator projection (see Section 2.4).

Second, the visual impact of each colour in the map is based on the relative areas of the enumeration units—an artefact of using an equivalent projection—with larger enumeration units drawing the eye first. While spatial area is important for many environmental SDG indicators, social and economic variables often are influenced more by population density. Dasymetric maps (see Section 3.5) and cartograms (see Section 3.8) are two alternatives for overcoming this limitation of choropleth maps. Notably, the issue of visual impact is exacerbated for small island developing nations that are imperceptible on world maps using a small cartographic scale. A point symbol, shaded following the choropleth classification scheme, can be added atop SIDS to ensure they remain visible in choropleth maps.

Third, colour value is an ordered visual variable that is not read quantitatively like the visual variable size used in proportional symbol maps (see Section 2.9). Accordingly, quantitative values are not reliably estimated from choropleth maps, requiring data classification into typically four to seven classes to simplify the number of colours in the map (see Section 1.9). In contrast, proportional symbol maps do not need to be classified and can portray a greater range of values through their symbolization, which may be helpful in portraying the spatial pattern of a given indicator.

Finally, the perception of colour varies considerably across map audiences, requiring colour-safe schemes for individuals with colour vision deficiency (see Section 4.2). Further, the reproduction of colour varies considerably across print and screen media (see Section 2.10). The visual variable size used in proportional symbol maps is read much more consistently across use and user contexts.

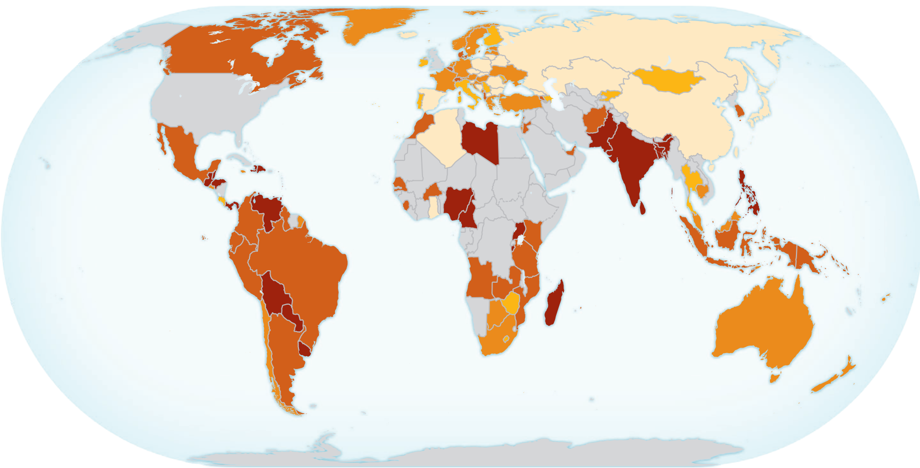


Figure 3.3-1 (Opposite side): Choropleth map. Indicator 16.3.2 (2015–2017, 3-year average) on unsentenced detainees held in prisons and jails is depicted as a choropleth map using a sequential colour scheme. The absolute number of unsentenced detainees is transformed into a percentage of total prison population because choropleth maps require normalized, relative values.

3.4 Proportional Symbol Maps

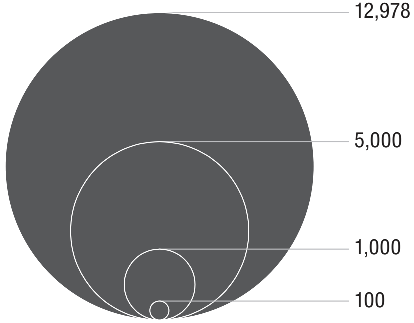
A proportional symbol map is a thematic map that scales the sizes of point symbols by their attribute values (see Section 3.1). Proportional symbol maps represent quantitative, often unnormalized absolute values and can represent either individual-level data (e.g., cities) or enumerated data by placing the point symbol at the centroid of the polygon. They employ size as the visual variable, enabling numerical visual comparisons among symbols (see Section 2.9).

Proportional symbol maps are useful for mapping economic SDG indicators as they evoke a metaphor of discrete and abrupt phenomenon, such as sites of production and distribution. Because of the strength of the visual variable size, readers can quickly assess the distribution of absolute values among different countries without paying attention to the political borders themselves. Accordingly, proportional symbol maps overcome many of the issues with normalization, projection, and classification that afflict choropleth maps (see Section 3.3) and, therefore, may be useful beyond economic indicators as well. For instance, one major advantage over choropleth maps for mapping indicator datasets is that proportional symbols can exceed the boundaries of their enumeration units, keeping small countries and small island states visible on world maps (**Figure 3.4-1**). Notably, proportional symbol maps can be used with the Web Mercator projection without impacting map reading (Section 4.5).

Despite advantages, proportional symbol maps have several unique design challenges including symbol scaling and symbol overlap. Most charting software uses ***mathematical scaling***, directly relating the area of the symbol to the attribute value. However, readers systematically underestimate proportional polygon (2D) symbols as they grow larger, with even more severe underestimation with proportional volume (3D) symbols (see Section 2.8). Therefore, mapping software often enables ***perceptual scaling*** to account for systematic underestimation. Proportional symbols can be classified to reduce visual complexity, a process described as ***range grading*** for proportional symbols with the resulting map called a ***graduated symbol map***. Range grading is a common option on world maps or bivariate maps, shading the proportional symbols by a second attribute value, to limit the total number of unique symbols in the map (see Section 3.6). The more complex the symbol shape, the more difficult the reading of relative proportions; thus, the shapes of proportional symbols typically are constrained to simple circles, squares (both 2D), or rectangular bars (1D).

Second, proportional symbols commonly exceed their enumeration unit boundaries and need to be re-symbolized or displaced to clarify their overlap (see Section 2.7). Two common strategies for managing overlap include the use of transparency or the use of an outer symbol stroke (the latter is used in **Figure 3.4-1**), with smaller symbols placed on top of larger ones; the two strategies should not be used together to maintain legibility. Alternatively, symbols can be displaced away from the centroid of the enumeration unit, with large displacements clarified with leader lines as with densely labeled regions.

Total Number of Infant Deaths Under Age One (2016)



Missing data or outside Europe region

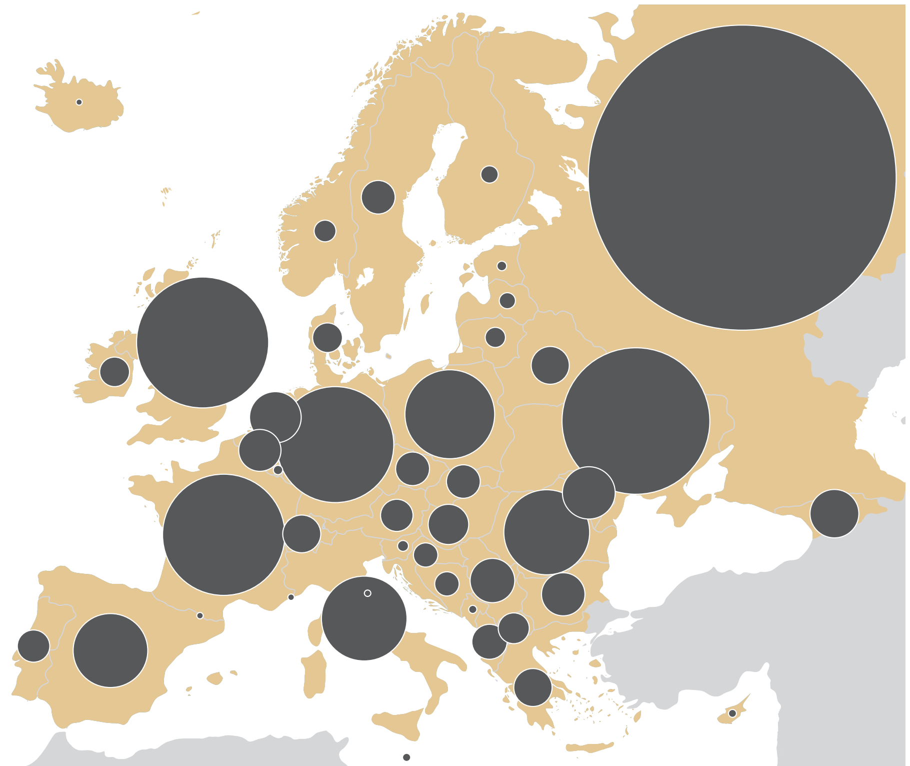


Figure 3.4-1 (Opposite side): Proportional symbol map. Indicator 3.2.1 (2016) on the total number of infant deaths under age one in the European region is depicted as a proportional symbol map using perceptual scaling for circular symbols. Because size is a numerically read visual variable, proportional symbol maps do not need to be classified. Symbol overlap is managed using a white symbol stroke with smaller symbols placed atop larger ones. Small countries by area such as Andorra, Luxembourg, Malta, Monaco, and San Marino remain visible on the map because the proportional symbols are allowed to exceed their political boundaries, an advantage of proportional symbol maps.

3.5 Dasymetric Maps

A ***dasymetric map*** leverages ancillary geospatial data to redraw borders of enumeration units—often at a finer spatial resolution—that better reflect the spatial distribution of the mapped phenomenon. While choropleth maps of the SDG indicators evoke a visual metaphor of continuous phenomena that changes only at international boundaries (see Section 3.3), often there is a great amount of variability within each enumeration unit. In other words, global SDG indicators provide only a coarse look at disparities in environmental sustainability, social inclusion, and economic prosperity. Dasymetric maps can support more localized monitoring and policymaking in lieu of higher-resolution subnational datasets harmonized across countries.

There are two kinds of ancillary data useful for a dasymetric map: exclusionary and inclusionary. ***Exclusionary data*** defines locations where the mapped phenomenon cannot exist. For instance, trees cannot grow above a certain elevation, in a desert receiving a minimal amount of precipitation, or in a lake or river. Thus elevation, annual precipitation, and land cover can be used as exclusionary factors in a dasymetric map of protected forests. ***Inclusionary data*** defines locations where the mapped phenomenon can exist, often in different amounts. For instance, rural versus suburban versus urban zoning can be used to weight the occurrence of social phenomenon based on the average population densities for these zones in a given country (e.g., 10 people per km in rural, 100 people per km in suburban, 1,000 people per km in urban).

A dasymetric map can be generated in mapping software using several geospatial processes. First, the absolute values for each enumeration unit are calculated, with relative values reverted to the original frequency tally (e.g., multiplied by area for densities, multiplied by population for per capita rates, etc.) (see Section 1.7) (**Figure 3.5-1**). Next, relevant ancillary data are used to identify areas where the mapped phenomenon is excluded or included (**Figure 3.5-2**). Then, vector or raster math is performed to dissolve the original enumeration unit into subareas for exclusion and inclusion of the mapped phenomenon (**Figure 3.5-3**). The absolute values are redistributed within these finer resolution boundaries, exclusionary areas getting no value and inclusionary areas given values based on predetermined weights. Finally, the redistributed absolute values are normalized into relative values for mapping, producing a new set of shaded areas that provide greater detail about the spatial distribution of the SDG indicator (**Figure 3.5-4**). These boundaries often are generalized for the map purpose and cartographic scale (see Section 2.7). The dasymetric technique can alter the boundaries for any thematic map but most commonly is applied for choropleths when mapping the SDG indicators.

The United Nations does not provide ancillary information to make dasymetric maps, and the best quality ancillary data likely is specific to each nation's spatial data infrastructure, making dasymetric mapping at a global scale difficult.

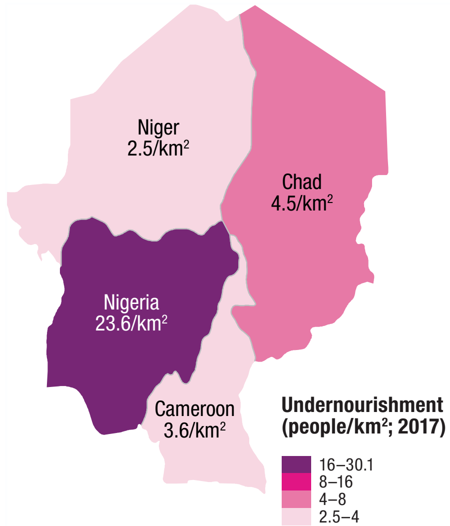


Figure 3.5-1: Original choropleth map. Indicator 2.1.1 (2017) on the number of undernourished people per km^2 is mapped for four countries in Sub-Saharan Africa.

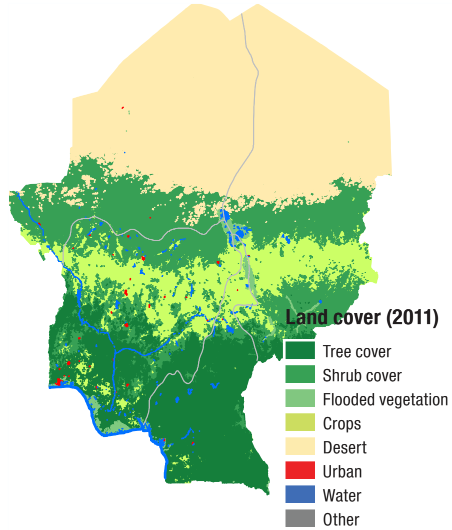


Figure 3.5-2: Exclusionary data. Classified land cover (2011) processed from satellite imagery is used to identify areas where people do not live: desert and water.

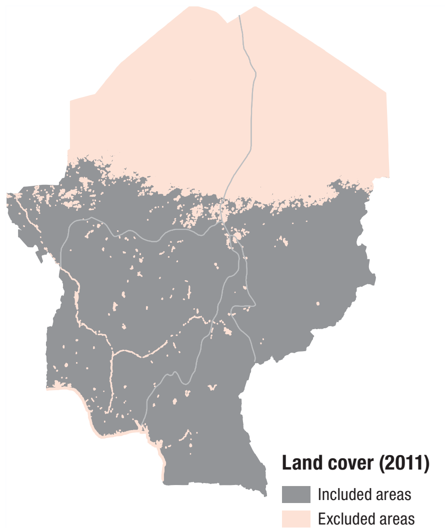


Figure 3.5-3: Vector math. Vector math is applied to remove the desert and water classes from the enumeration unit. Large areas in the north are removed due to the location of the Sahara Desert as well as smaller water bodies such as Lake Chad and the Niger River.

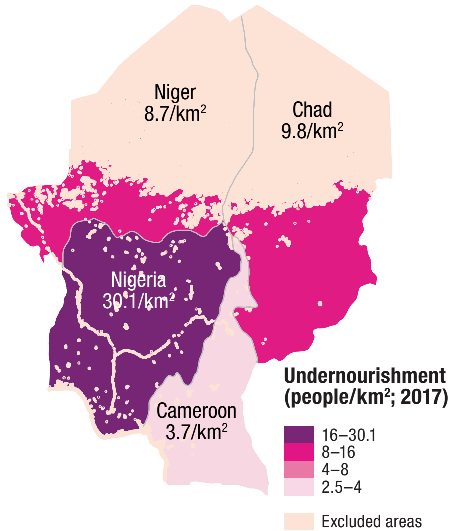


Figure 3.5-4: Resulting dasymetric map. Indicator 2.1.1 (2017) on the number of undernourished people per km^2 is remapped with a new area denominator. As a result, Niger and Chad have a much greater density, pushing them into higher choropleth classes.

3.6 Map Legends

A ***legend*** or ***key*** provides a description of each kind of symbol included in the map. The legend clarifies the primarily visual map symbols with text, which might include qualitative category names or quantitative numbers. Not all maps require legends, and proper use of the visual variables enable audiences to see immediately the broader map patterns without first referencing specific symbol values (see Section 2.9).

Effective legend design is important for maps made for general audiences that may have little background knowledge in the mapped phenomena, such as SDG maps designed for awareness and outreach. The legend provides an opportunity to introduce and explain the broader SDG as well as frame the narrative by marking critical values such as the current average or future desired level (see Section 4.7). In this way, the legend is an exercise in education, providing instructions in how to interpret and, therefore, make use of the map itself. To this end, the legend title for SDG maps should restate the full location, attribute, and temporal context (see Section 1.2) rather than or in addition to listing a specific indicator number to prevent look-up. Effective legend design and legend titles are particularly important for SDG maps distributed across diverse audiences, as specific symbols and phrasings may have variable cross-cultural meanings requiring translations (see Section 4.1).

General guidance suggests that all point, line, and polygon symbols included in the map should be included in the legend. However, it is common to exclude symbols at the lowest level of the visual hierarchy (see Section 2.13), serving more as basemap reference (e.g., political borders, water versus land).

Thematic map legends often include just the symbols that encode the thematic layer (see Section 3.1). For thematic maps, every symbol in a classed scheme should be included in the legend, but only three to five representative symbols need to be included for an unclassed scheme (see Section 1.9). Nominal thematic maps depicting qualitative data should include gaps between legend items to evoke a metaphor of discrete categories, while choropleth, proportional symbol, etc., maps depicting quantitative values should not include gaps to evoke a metaphor of a continuous number line, even when classed. Quantitative thematic maps also should evoke a "more equals higher" metaphor by placing the lowest value on the bottom when legend items are stacked vertically. **Figures 3.6-1**, **3.6-2**, and **3.6-3** display the legend specifications used for this book for nominal maps (see Section 3.2), choropleth maps (see Section 3.3), and proportional symbol maps (see Section 3.4) respectively.

Finally, nearly all legend designs can be improved by combining the design with a diagram (see Section 3.10), such as a bar chart or histogram showing the distribution of map features in each class (see **Figure 1.9-1**). Legends also can be reinforced or completely replaced with interaction (see Section 4.3), bringing the legend or exact data value into the map as the user probes or selects a specific feature.

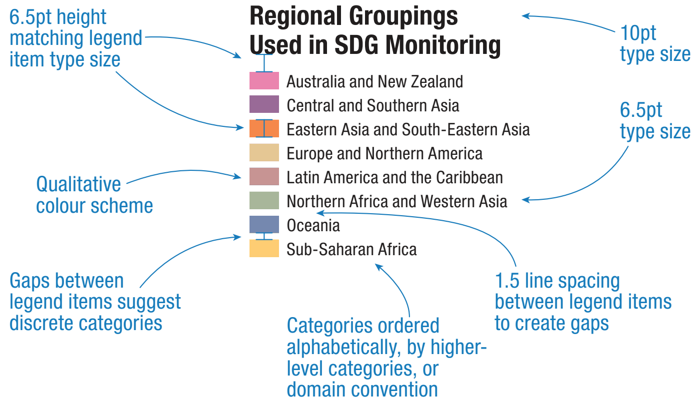


Figure 3.6-1: Nominal map legend. The nominal legend specifications for this book use a qualitative colour scheme adapted from the SDG icon colours. There is a gap between legend items to suggest discrete categories. Each legend item is the same height as the legend label type size, with 1.5 line spacing to create the discrete gaps. Nominal legend items are arranged alphabetically in this book.

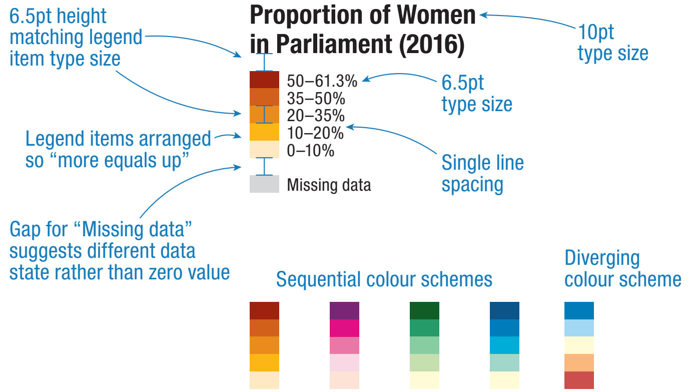


Figure 3.6-2: Choropleth map legend. The choropleth map legend specifications for this book rotate among five sequential and diverging colour schemes. No gap is included between legend items to suggest a continuous number line. The "Missing data" category is offset with a gap to suggest a different data state rather than a zero value. Legend items are arranged so that "more equals up".

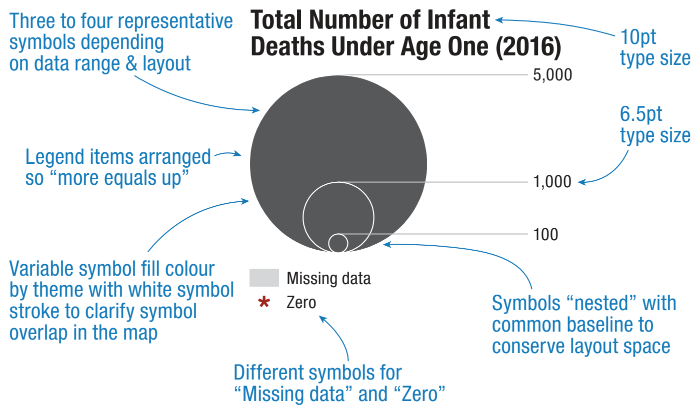


Figure 3.6-3: Proportional symbol map legend. The proportional map legend specification for this book includes three to four representative symbols depending on the data range and layout. Symbols are arranged so that "more equals up" and "nested" with a common baseline to conserve layout space. Separate symbols are provided to clarify "Missing data" and "Zero", when relevant to the mapped dataset.

3.7 Bivariate Maps

A ***bivariate map*** (bi=two, variate= variables) depicts two data attributes in a single thematic map. Bivariate maps can be powerful for visual interpretation of spatial patterns, particularly for comparing the spatial distribution of two potentially related SDG indicators as well as for identifying outlier locations that do not conform to an expected relationship between SDG indicators. However, bivariate maps can be confusing and even misleading because they exhibit increased information complexity and are found less frequently in popular media.

In practice, it is useful to consider three kinds of bivariate maps based on combinations of the visual variables: separable (e.g., thematic map combinations, shaded cartograms, shaded proprtional symbols), integral (e.g., bivariate choropleth maps), and configural (e.g., split symbol maps). Bivariate map legends should be plotted with X- and Y-axes to show all possible symbol combinations (**Figure 3.7-1**) and, thus, inform how each symbol combination should be read in the resulting map.

A ***separable*** bivariate map preserves reading of both original X and Y indicators in the map, with a separable map functionally serving like two different maps on a single page (**Figure 3.7-2**). Use separable maps for independent indicators with different attribute units, such as comparing an absolute frequency to a relative percentage or an unnormalized indicator to a normalized variant.

An ***integral*** bivariate map restricts reading of the original X and Y indicators but promotes reading of the + relationship between indicators, making it easier to infer correlations and identify places that do not conform to the expected relationship (**Figure 3.7-3**). Use integral maps for dependent indicators in the same attribute units for visual correlation. Avoid integral maps when there is no known correlation as they can be misleading and infer a causal relationship.

A ***configural*** bivariate map maintains reading of the original X and Y attributes while including a visual hint about the + relationship that can be used for visual correlation (**Figure 3.7-4**). Use configural maps for independent indicators in the same attribute units. These are useful for comparing temporal changes, such as before versus after, or subsets within an indicator, such as rural versus urban.

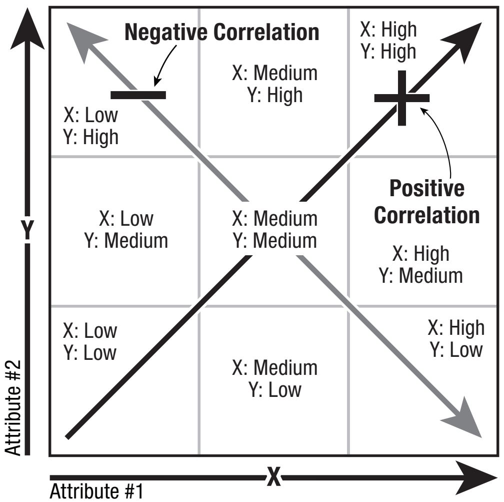


Figure 3.7-1: Reading bivariate maps. Bivariate map legends can be arranged in two dimensions to show example symbol combinations. Different bivariate map types then vary by how the X- and Y-axes and positive (+) correlation are preserved.

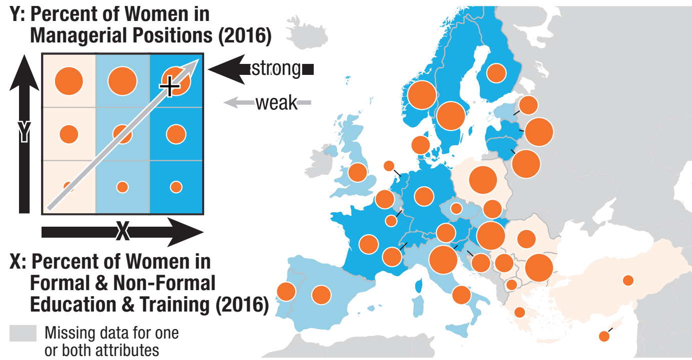


Figure 3.7-2: Separable bivariate map. Indicator 4.3.1 (2016) on the per cent of women in formal and non-formal education and training is mapped as a choropleth and Indicator 5.5.2 (2016) on the per cent of women in managerial positions is mapped with proportional symbols. Separable maps preserve X and Y but do not have an emergent positive (+) dimension.

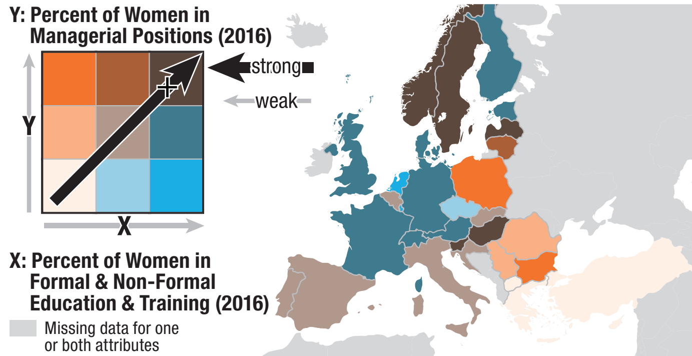


Figure 3.7-3: Integral bivariate map. Indicator 4.3.1 (2016) and 5.5.2 (2016) are remapped using a bivariate choropleth, which has an emergent positive (+) dimension. Because both indicators have the same attribute unit (percentages), the bivariate choropleth map is a better solution than the thematic map combination in **Figure 3.7-2**.

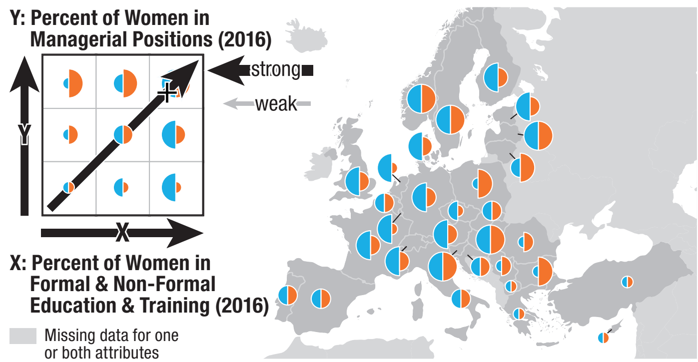


Figure 3.7-4: Configural bivariate map. Indicator 4.3.1 (2016) and 5.5.2 (2016) are remapped as a split proportional symbol map. Configural solutions preserve X and Y but also have an emergent + dimension. The split proportional symbol map is more appropriate than the **Figure 3.7-3** bivariate choropleth if independence between attributes is assumed.

Integral and configural bivariate maps usually are classified into just 2x2 or 3x3 classes to reduce complexity (e.g., 3x3 results in nine unique bivariate symbols). Separable bivariate maps can include 4x4, 5x5, or even 7x7 classes much like univariate maps since it is possible to attend to the X and Y attributes separately (see **Section 1.9**).

3.8 Cartograms

A ***cartogram*** is a thematic map that scales the area of each enumeration unit by its attribute value. Like a proportional symbol map, a cartogram uses the visual variable size to depict quantitative differences. However, a cartogram changes the size of the entire enumeration unit, rather than a symbol placed at the centroid of the enumeration unit . Accordingly, cartograms often show dramatic differences among regions, shocking the audience out of their preconceived understandings to encourage critical geographic thinking about the mapped area (**Figure 3.8-1**).

Cartograms deliberately distort the size, shape (or more specifically angular relationships; see Section 2.4), and/or topological relationships (i.e., shared boundaries) of the enumeration units they represent. Different cartogram techniques can be compared by how well they preserve or distort these characteristics (**Figure 3.8-2**).

A ***contiguous*** cartogram maintains topology between enumeration units while compromising on shape. For instance, the diffusion-based contiguous cartogram maintains all adjacent edges, often resulting in unfamiliar boundaries while preserving regional-level map patterns. In contrast, a ***non-contiguous*** cartogram maintains shape completely by scaling each enumeration unit within its boundary, making it easy to identify each

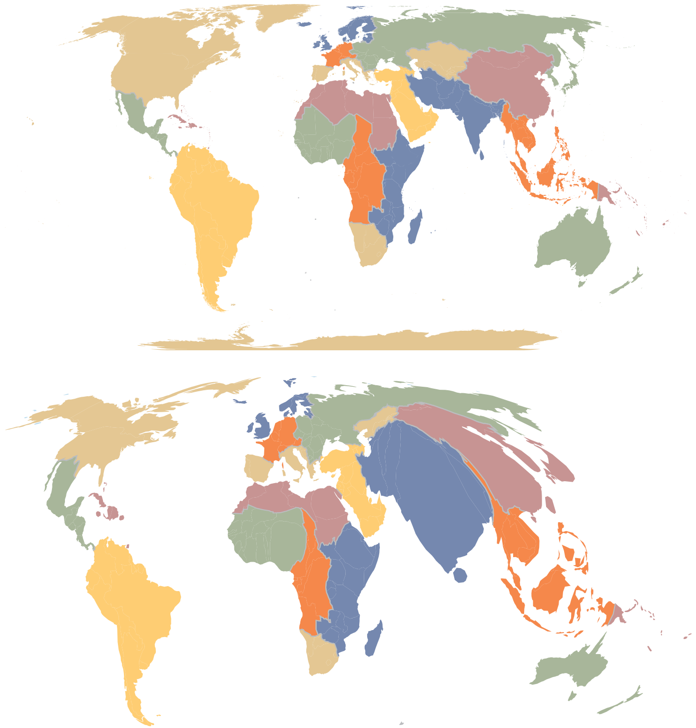


Figure 3.8-1: Explaining cartograms. The pair of maps depicts M49 sub-region and intermediate region groupings in a nominal map. **Top:** SDG regional groupings projected into the Eckert IV equivalent projection used throughout this book. Background context is removed for comparison. **Bottom:** SDG regional groupings mapped in a contiguous cartogram based on population within each regional grouping. In this example, the cartogram has the advantage of providing more map space for locations with more people, drawing relative visual attention away from North and South America and towards Africa and Asia. Accordingly, the cartogram may be a more useful map when thinking geographically about population-based human and social phenomena.

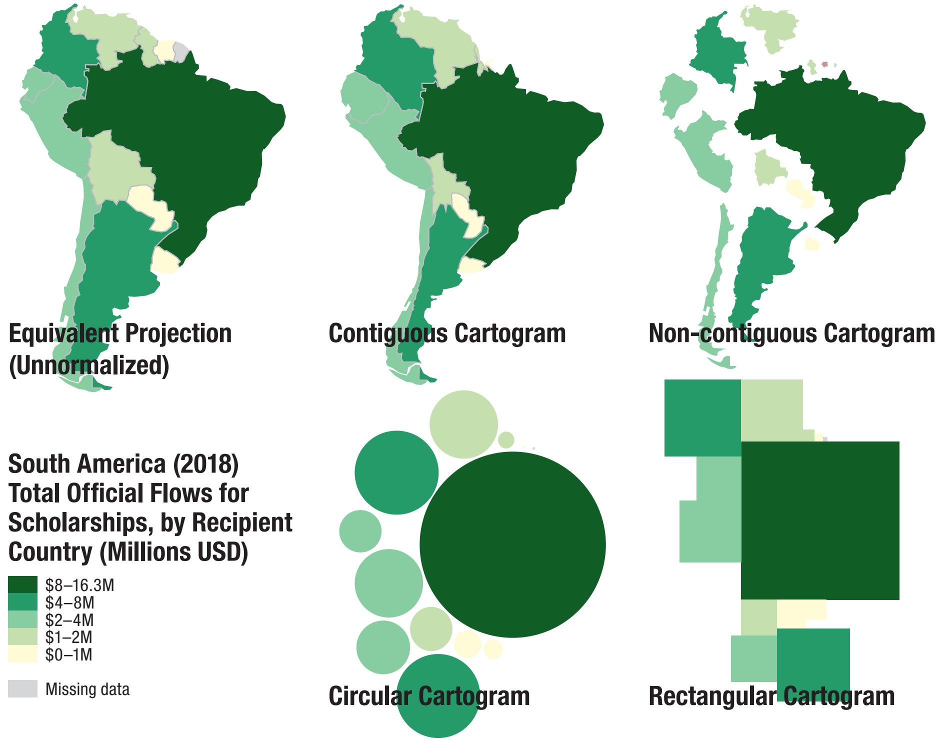


Figure 3-8.2: Types of cartograms. Indicator 4.b.1 (2018) on the total official flows for scholarships, by recipient country (Millions USD) is mapped for South American countries as a choropleth atop four different population-based cartograms. **Top-centre:** Contiguous. **Top-right:** Non-contiguous. **Bottom-left:** Circular. **Bottom-right:** Rectangular.

enumeration unit, but it creates large gaps between polygons as a result that impact reading of broader map patterns.

Other "pseudo"-contiguous solutions follow a more schematic approach. For instance, circular and square cartograms replace all enumeration units with proportional symbols, preserving size perfectly while sacrificing completely on shape. Pseudo-contiguous cartograms differ from proportional symbol maps in that the basemap context is removed and the symbols themselves are displaced to preserve topology.

Cartograms can be shaded by a second variable to produce a bivariate map (see Section 3.7). For the SDG indicators, the cartogram itself is based on an ***equalizing variable*** like population to produce a new, more relevant set of geographic boundaries. The colour shading then is used for the indicator or ***variable of interest***. Bivariate cartograms should be made using absolute rather than relative values (see Section 1.4), as the equalizing variable "visually normalizes" the variable of interest in the same way relative values are "statistically normalized".

3.9 Maps & Time

Time describes the *when* of data (see Section 1.5). Time is implicit in all maps, but this is not always that obvious in the design. Most of the SDG maps in this book depict an indicator at a single time stamp, such as a national census, or a single time interval, such as the accumulation of activities or events over a single year. While these maps show a single snapshot or window in time, maps *of time* represent a time *series* of multiple time stamps or intervals to facilitate understanding of patterns and trends over time. Such time series maps, therefore, are essential for monitoring progress toward the SDGs.

As with representing uncertainty (see Section 2.15), maps of time require creative design solutions, as showing even two different time stamps or intervals doubles the amount of data in the map. As such, time series maps quickly grow in complexity. There are three primary ways to represent time on maps: adjacent maps, a single coincident map, and animation.

Adjacent maps separate the time series into different maps. The adjacent maps are held consistent for projection, classification, symbolization, etc., but vary in the depicted time stamp or interval from the time series (**Figure 3.9-1**). Adjacent maps often are called ***small multiples*** when used for a time series because dozens of postage-stamp-sized maps may be included in the layout (compared to the pairwise adjacent maps of data and their certainty; see **Figure 2.15-2**). Accordingly, adjacent maps or small multiples have the advantage of maintaining much of the nuance across the time series, but they must use more generalized basemaps and smaller cartographic scales to account for the reduced page space for each individual map and to accommodate the complete time series altogether.

A single coincident map depicts a time series by treating time like an attribute and applying a visual variable appropriate for an ordinal level of measurement (Section 2.9), such as changing colour value in a sequential scheme from light-to-dark. Such extrinsic and coincident solutions work best for points and lines that can be overplotted as separate layers and, thus, do not work well for time series data enumerated to polygonal features like the SDG indicators.

Instead, a ***change map*** can be used for the enumerated indicator data that calculates the difference between two data captures in the time series—typically mapped as per cent increase or decrease. The per cent change then is represented intrinsically with a diverging colour scheme centred on zero per cent change (**Figure 3.9-2**). Notably, a change map is an additional way to normalize enumerated data not discussed in Section 1.7. While a change map reduces complexity, it loses information about patterns and trends, particularly cyclical trends (see Section 1.5) within the time series, to focus only on the first and last data captures (or any selected two states in-between).

Animation uses digital display time to change the map display, progressing through the time series one data capture at a time (**Figure 3.9-3**). Animation

Figure 3.9-1: Small multiples of a time series. Indicator 7.2.1 (2000–2015; five-year intervals) on renewable energy share of total final energy consumption is mapped for Western Europe as adjacent maps. The resulting small multiples have a smaller cartographic scale and less detail given the reduced page space.

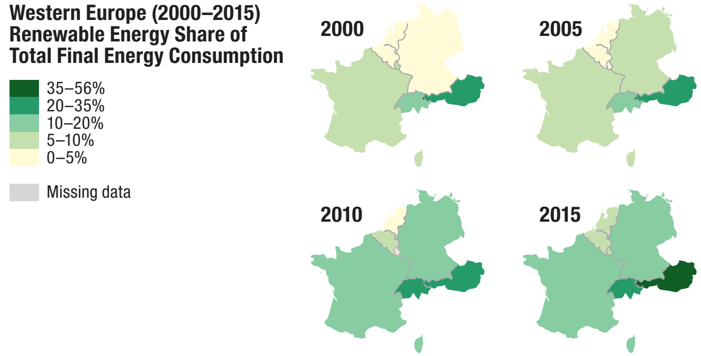


Figure 3.9-2: A change map between time intervals. Indicator 7.2.1 is remapped for Western Europe as a single coincident map. Here, only 2000 and 2015 are mapped, resulting in a normalized per cent change relative to average increase (5.6%) in renewable energy share of total final energy consumption.

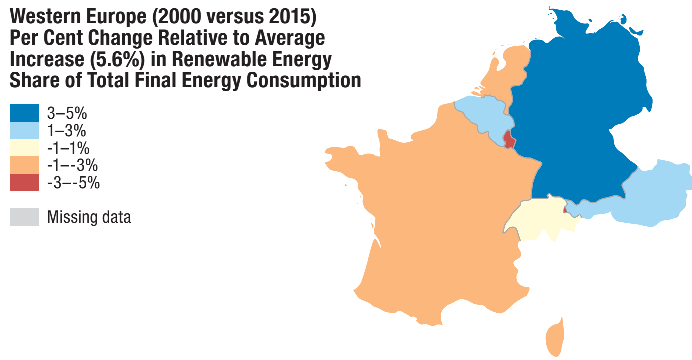
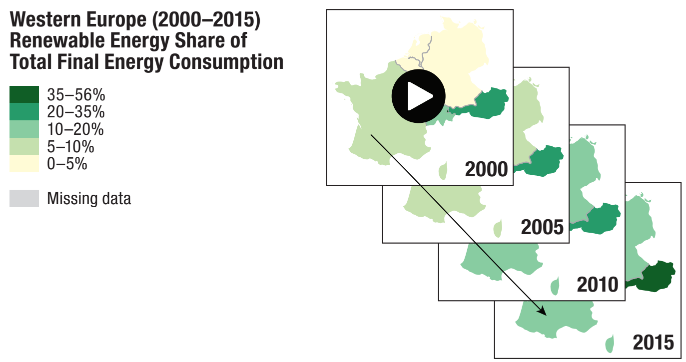


Figure 3.9-3: Animation of a time series. Indicator 7.2.1 (2000–2015; five-year intervals) is represented in a conceptual animation for Western Europe. The animation is similar to the **Figure 3.9-1** small multiples, but display time is used to progress through the time series one map at a time (see Section 4.8).



requires a dynamic map use environment and, therefore, is not possible for print mapping. Animations give an overall sense of trends across time and are well-liked by general audiences. However, the audience often misses a large amount of changes in the display, resulting in a bias towards patterns in the first and last data capture. Section 4.8 provides additional discussion on animated maps.

3.10 Diagrams

A ***diagram***—also commonly referred to as a ***chart*** or ***graph***—represents non-geographic attribute and temporal data patterns, such as overall range and distribution, outliers and anomalies, trends over time, or correlations between phenomena.

In maps, the visual variable location is used to encode the projected spatial location of each geographic feature, with the other visual variables then used to encode additional qualitative or quantitative attributes about these features (see Section 2.9). In contrast, diagrams use the visual variable location to position each data element into a non-geographic coordinate frame that evoke spatial metaphors among features within the coordinate frame, such as near-far, connected-disconnected, and inside-outside. Accordingly, the choice of axes, their coordinates, and other visual partitioning is key to interpreting the resulting non-spatial diagrams and their symbols. However, this also makes cartography perhaps the most challenging information visualization context, as the visual variable location must be used to represent spatial information directly, constraining design alternatives.

As with thematic maps (see Section 3.1), there are many kinds of diagrams available for visualizing the SDG indicators. **Figure 3.10-1** classifies common diagrams by those suitable for one, two, or more attributes and those for representing attributes over time. There are many additional types of diagrams that may be useful for understanding the SDG indicators, but they all rely on the same principles of data type conversions (see Section 1.7), dimensionality (see Section 2.8), and symbolization (see Section 2.9) described previously. Maps and diagrams regularly are combined into a single layout to emphasize complementary components of an indicator, with each geographic feature in the map also given a symbol in the associated diagram (see Section 3.13). As introduced in Section 3.6, nearly any legend can be improved by integrating it with a diagram.

In addition to location, many diagrams directly use the visual variable size to encode quantitative data. Example diagrams using size include bar charts, bubble charts, and stacked area charts. Several diagrams also have emergent shape or orientation cues, including line charts, pie charts, slope charts, and stream graphs. Many diagrams can be modified with colour hue to redundantly encode information or to denote higher-level categories within the diagram, such as the M49 regions and subregions.

Figure 3.10-1 (Opposite side): Choosing a diagram. Section 3.11 treats univariate diagrams for single attribute values. Section 3.12 discusses comparative diagrams depicting proportions or related values within single attributes. Section 3.13 describes bivariate and multivariate diagrams for comparing multiple attributes. Finally, Section 3.14 concludes with temporal diagrams for a single attribute over time.

3.11 Univariate Diagrams

A first category of diagrams depicts the distribution of a single attribute, described as ***univariate***. For instance, a ***bar chart*** depicts the distribution of an attribute across different nominal categories, such as SDG regional groupings or individual countries. Accordingly, bar charts are useful for comparing a single indicator by geography to sort by high and low data values and clusters of similar values within this range. A bar chart is visually similar to a ***histogram***, but rather than nominal categories, a histogram bins numerical data into mutually exclusive and exhaustive classes (e.g., **Figure 1.9-1**). Histograms are useful for understanding the data distribution of a single indicator and choosing class breaks. Given their distinction between nominal and numerical data, bar charts are commonly integrated into nominal map legends and histograms into choropleth map legends.

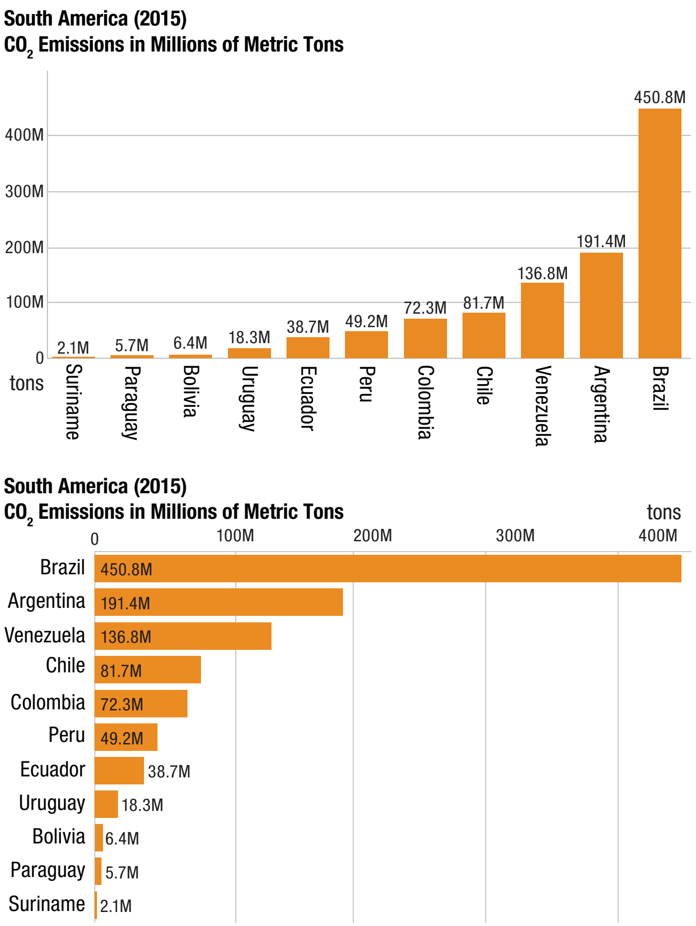
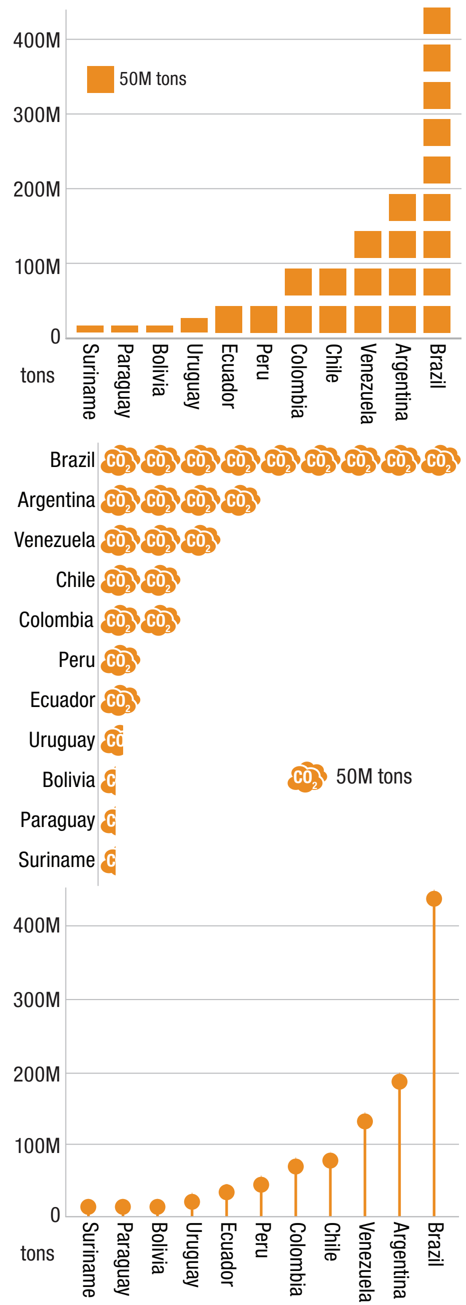


Figure 3.11-1: Bar charts. Indicator 9.4.1 (2015) on CO_2 emissions in metric tons is plotted for South American countries in a pair of bar charts. **Top:** The more common vertical orientation uses a top=more visual metaphor as larger data values grow into taller bars, but the vertical orientation requires rotated bar labels, inhibiting readability. **Bottom:** The less common horizontal orientation improves legibility of the bar labels much like a map legend but may result in an imbalanced, top-heavy visual layout.

Figure 3.11-2 (Opposite side): Alternative single indicator diagrams to bar charts. Indicator 9.4.1 (2015) on CO_2 emissions in metric ton is replotted for South American countries using three alternative diagrams for single indicators. **Top:** Unit chart (vertical). **Middle:** Pictorial unit chart (horizontal). **Bottom:** Lollipop chart (vertical).



Bar charts and histograms can be oriented vertically or horizontally (**Figure 3.11-1**). A vertical bar chart, also called a ***column chart***, has vertical labels that can be cumbersome to read, especially for longer place names. Thus, the lesser common horizontal orientation may be preferable for diagrams on the indicators, reading top-down much like a map legend (see Section 3.6) although producing an imbalanced layout (see Section 2.13). The bars should be ordered from high-to-low or low-to-high, not alphabetically. Three-dimensional (3D) bar charts are not recommended, as the perspective makes it difficult to correctly read and compare bar heights or lengths (see Section 2.8).

Alternatives to bar charts and histograms include unit charts, pictorial unit charts, and lollipop charts (**Figure 3.11-2**). Like a bar chart, a ***unit chart*** relies on the visual variables location and size but adds the design embellishment of a regular grid to enable counting of exact frequencies and easier comparison of distant bars. A ***pictorial unit chart*** modifies the regular grid of the unit chart by stacking iconic point symbols (see Section 3.2). Pictorial unit charts are a good choice for a general audience, as the iconic pictograph evokes a stronger visual metaphor of the mapped phenomenon. Finally, a ***lollipop chart*** uses a more minimal line anchored with a point symbol at the data value, taking up less overall space in the layout.

3.12 Comparative Diagrams

A second category of diagrams supports comparisons within a single attribute, such as sub-category breakdowns reported within a single SDG indicator.

Several diagrams support comparison of relative values (**Figure 3.12-1**). The most common diagram showing relative proportions is a ***pie chart***. Pie slices within the chart have emergent size and shape visual cues based on relative percentages. Many cartographers are critical of pie charts, as it is difficult to compare pie slices of different sizes and shapes due to their inconsistent orientation around the circular pie. Additional common mistakes with pie charts include using percentages that do not add up to 100 per cent and depicting pie charts in 3D (as with bar charts; see Section 2.8), as the perspective distorts the orientation angles and, thus, the represented values. Despite limitations, pie charts can be useful for comparing a single sub-category to the overall total, especially for identifying proportions that are near right-angle orientations of 25 per cent, 50 per cent or 75 per cent.

A ***donut chart*** modifies the pie chart by removing the centre, emphasizing the relative size of the donut slice over the shape of the subdivisions (see Section 2.9). A ***waffle chart*** further improves reading and comparison of exact percentages by infilling a ten-by-ten-square grid, with each cell representing one per cent.

Other diagrams support comparison of absolute values instead of or in addition to relative values (**Figure 3.12-2**). A ***stacked bar chart*** divides a bar chart to show relative contributions to the total from sub-categories. A ***Marimekko chart*** normalizes a stacked bar chart to compare both relative percentages (read in either the X- or Y-axis) and absolute totals (produced by the areas of shaded polygon divisions produced by the combined height and width).

Finally, two diagrams specifically support pairwise comparison of complementary sub-categories (e.g., urban/rural, male/female) or two attributes in the same unit (**Figure 3.12-3**). A ***dumbbell chart*** enables easier comparisons of multiple enumeration units by depicting the pair of sub-categories as a single-size interval. A ***slope chart*** modifies the dumbbell chart to include an emergent orientation visual cue, suggesting an increase or decrease between sub-categories instead of difference.

Notably, dumbbell charts and slope charts are good choices for showing two sub-categories of an indicator that may not total 100 per cent, such as the urban/rural and male/female examples. Dumbbell and slope charts also can depict changes over time (see Section 3-14).

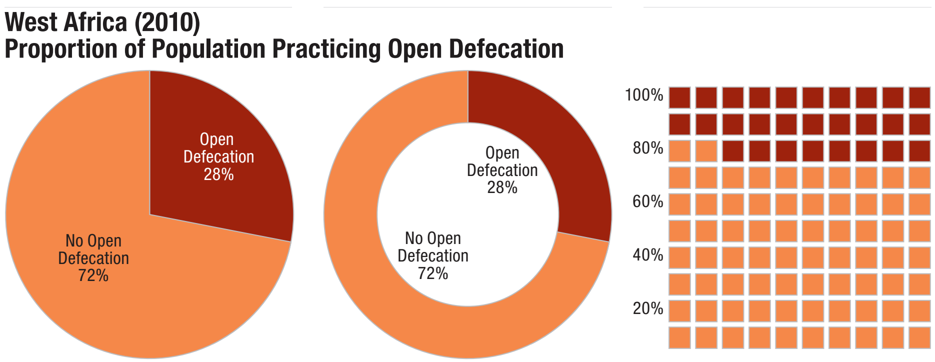


Figure 3.12-1: Diagrams for comparing relative values. Indicator 6.2.1 (2010) on the proportion of the population practicing open defecation is plotted as relative values for the Western Africa intermediate region. **Left:** Pie chart. **Centre:** Donut chart. **Right:** Waffle chart.

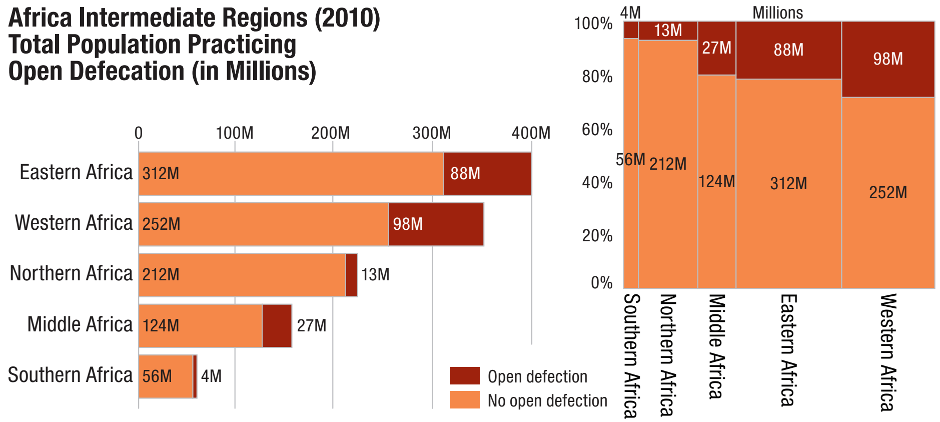


Figure 3.12-2: Diagrams comparing absolute values. Indicator 6.2.1 (2010) on the total population practicing open defecation is plotted for Africa intermediate regions. **Left:** Stacked bar chart. **Right:** Marimekko chart.

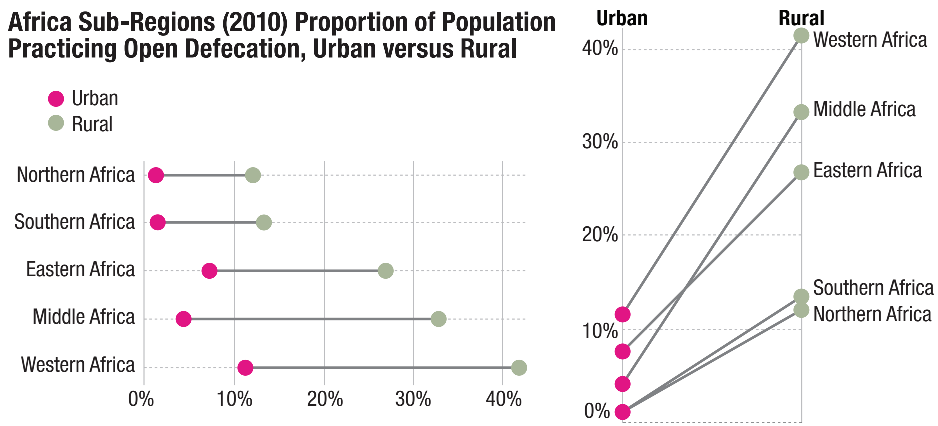


Figure 3.12-3: Diagrams comparing binary categories. Indicator 6.2.1 (2010) urban versus rural proportion of population practicing open defecation is plotted for African intermediate regions **Left:** Dumbbell chart. **Right:** Slope chart.

3.13 Multivariate Diagrams

A third category of diagrams depicts relationships among multiple attributes. Diagrams often are included alongside bivariate and multivariate maps to show the relationships among multiple attributes in statistical space in addition to geographic space (see Section 3.7).

A ***scatterplot*** depicts enumeration units such as countries or M49 regions as point coordinates in a two-dimensional statistical space (**Figure 3.13-1**). Scatterplots are useful for visually exploring possible correlations between two indicators, suggesting potential drivers or

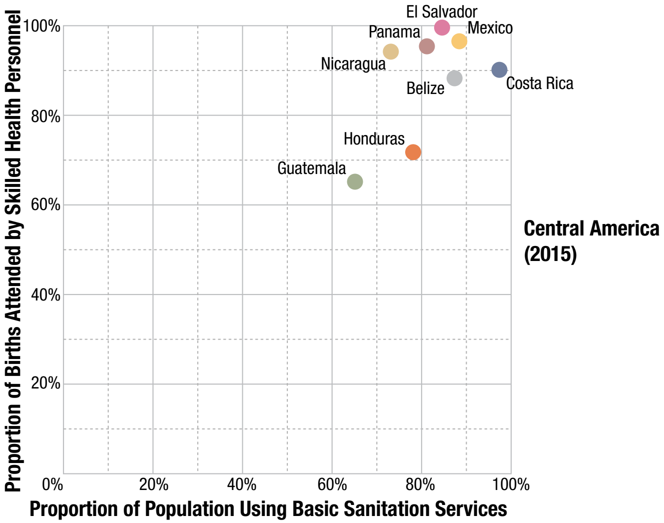


Figure 3.13-1: Scatterplot. Many SDGs are interconnected globally, such as wealth (SDG #1, No Poverty) and health (SDG #3, Good Health & Well-Being). Multivariate diagrams like scatterplots enable exploration of potentially correlated indicators and identification of outliers. The proportion of population using basic sanitation services (Indicator 1.4.1, 2015) is plotted on the X-axis of the scatterplot and the proportion of births attended by skilled health personnel (Indicator 3.1.2, 2015) on the Y-axis, resulting in a relatively strong correlation between these wealth and health indicators in Central America.

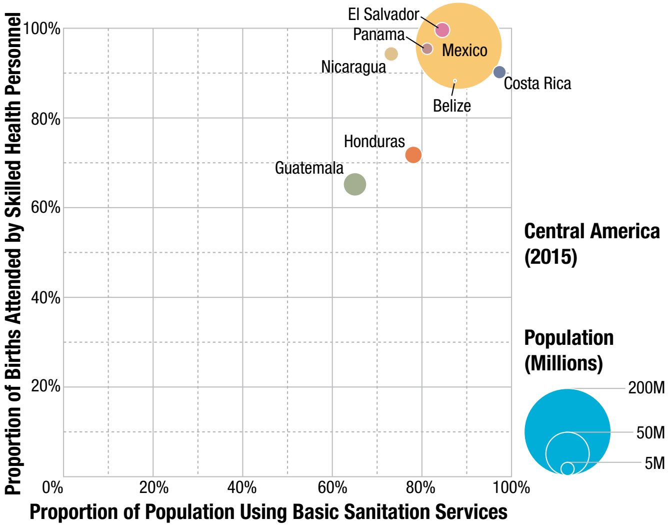


Figure 3.13-2: Bubble chart. While a scatterplot relies on the visual variable location to plot two attributes in a two-dimensional coordinate frame, a bubble chart adds a third attribute using the visual variable size. The scatterplot points from **Figure 3.13-1** are resized by the total population of each Central American country to provide a sense of the number of people impacted by the relatively better or worse conditions in wealth and health. The colour of **Figures 3.13-1** and **3.13-2** relates to the linked map in **Figure 3.13-3**. A 3x3 classification could be applied to the scatterplot or bubble chart to result in a bivariate choropleth map (see Section 3.7).

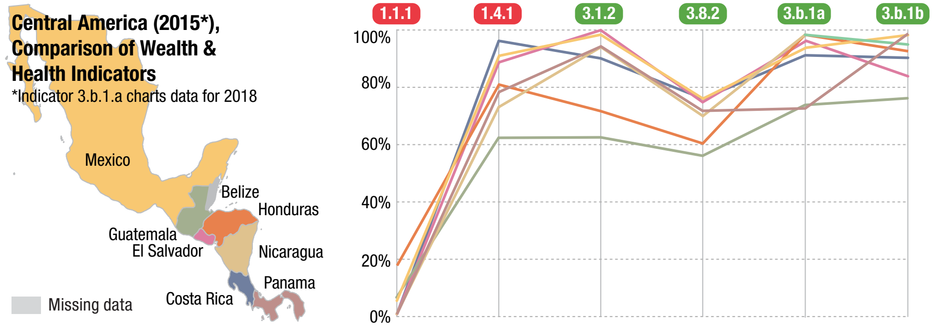


Figure 3.13-3: Parallel Coordinate Plot. The parallel coordinate plot extends the **Figure 3.13-1** scatterplot to chart six indicators related to wealth (SDG 1 No Poverty, red coordinates) and health (SDG 3 Good Health & Well-Being, green coordinates). Here, the map serves as a legend for interpreting the line colour in the parallel coordinate plot. Both map and parallel coordinate plot could be interactively coordinated to support exploration (see Section 4.10).

impacts of the indicators. As with bivariate maps, visual correlations in scatterplots do not necessarily imply causation.

A ***bubble chart*** is a variant of a scatterplot that depicts a third attribute by resizing the point symbol, resulting in a diagram that works much like a proportional symbol map (see Section 3.4). **Figure 3.13-2** modifies **Figure 3.13-1** to include population as a third variable, giving a better sense of the number of people impacted by the correlation.

Beyond bubble charts, there are a number of more complex diagrams for representing three or more attributes, commonly described as ***multivariate*** data. A ***parallel coordinate plot*** extends the spatial metaphor of a scatterplot to align three or more coordinate frames in a linear rather than orthogonal (right angle) layout (**Figure 3.13-3**). Data elements, such as M49 regions, subregions, or countries, are then woven as a line trace through each of the coordinates. Parallel coordinate plots are good for showing positive and negative correlations between sets of attributes, particularly when the order of coordinates can be rearranged interactively (see Section 4.4).

A ***radar chart*** or ***star plot*** arranges three or more coordinates circularly rather than linearly in the parallel coordinate plot, with a common base or zero coordinate. Line traces through the coordinates form a star shape that is more compact than the elongated parallel coordinate plot, making it easier to arrange in the layout (see Section 2.13).

While most maps are limited to representing only two attributes (i.e., a bivariate map; see Section 3.7), diagrams of multiple attributes like star glyphs can be added to the centroid of enumeration units to create a multivariate map of three or more attributes. Multivariate maps work best in a digital environment where they can be explored interactively in coordination with other diagrams (see Section 4.10).

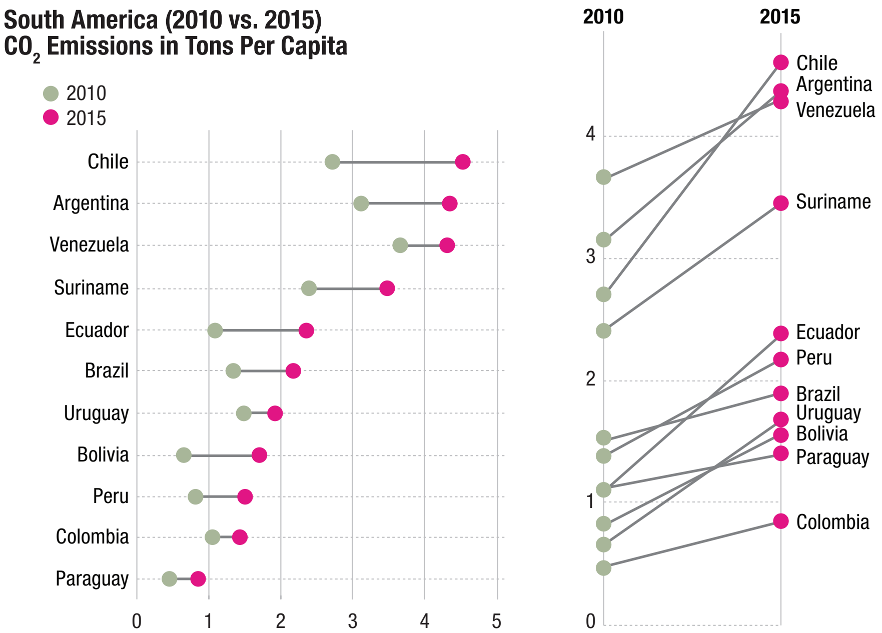
3.14 Temporal Diagrams

A final category of diagrams depicts an attribute over time. Like maps of time (see Section 3.9), diagrams of time are essential for monitoring progress towards the SDGs.

The dumbbell chart and the slope chart introduced in Section 3.12 also can be used to compare two time stamps or time intervals (**Figure 3.14-1**). These diagrams are particularly useful as companions to change maps of the SDG indicators (see Section 3.9), with the dumbbell or slope chart providing the pair of before/after values collapsed down to a single colour in the associated change map.

There are a number of additional temporal diagrams that represent trends across a complete time series (see Section 1.5; **Figure 3.14-2**). A ***line chart*** weaves a line trace through multiple time stamps or periods of a single attribute, producing a similar result as a parallel coordinate chart that weaves line symbols through multiple attributes collected at the same time (see Section 3.13). Line charts have an emergent orientation cue that represents increases versus decreases between each time stamp or interval. Lines often are coloured with different hues to distinguish individual features such as unique countries or denote higher-level categories like M49 regions.

A ***stacked area chart*** modifies the line chart by adding quantities on top of one another to combine towards the overall total, resulting in an additional cue of the visual variable size from the shaded polygonal area (see Section 2.9).



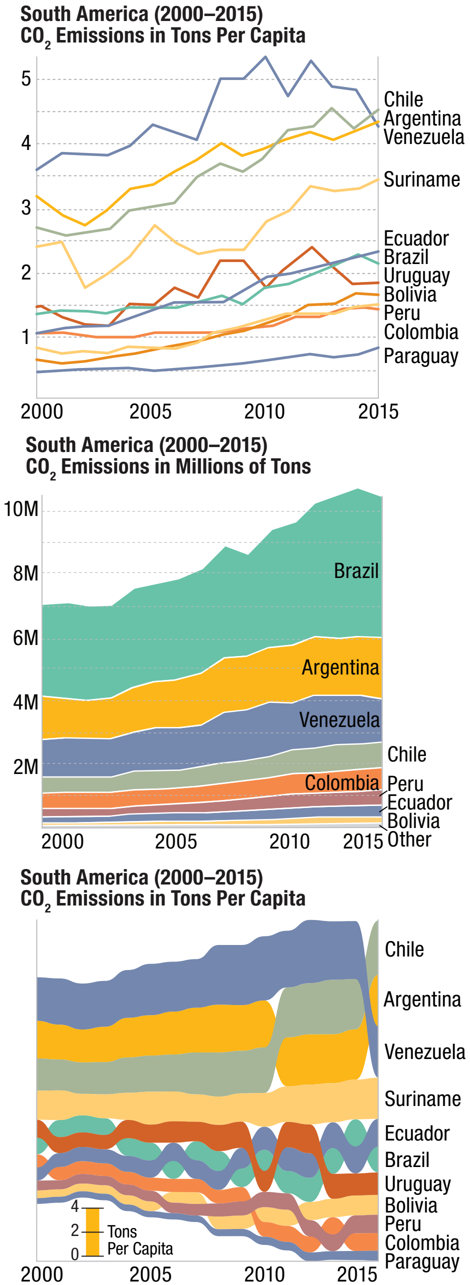
A disadvantage of stacked area charts is that the orientation of their borders depends on the area shapes "lower" in the stack, making it easy to interpret an increase as a decrease or vice versa.

A ***stream graph*** is an alternative that resizes a "stream" or conceptual line symbol, with thickness of the line symbol encoding the data value at a given time stamp or interval much like a numerical flow map (see Section 3.2). The stream graph symbols are centred upon a central horizontal baseline as opposed to a stacked area chart centred upon the coordinate baseline. A modified ***sorted stream graph*** reorders line symbols vertically across the diagram so that the largest value always is at the top of the diagram.

Finally, there are several diagrams that represent cyclical time, such as coxcombs and shaded calendars. Because indicator datasets currently do not include cyclical temporal data, these diagrams are not viable companions to SDG maps.

Figure 3.14-1 (Opposite side): Comparative diagrams of time. The pair of charts plots CO_2 emissions in tons per capita (Indicator 9.4.1) for 2010 versus 2015, showing an increase in all South American countries. **Left:** Dumbbell chart of time. **Right:** Slope chart of time.

Figure 3.14-2: Time series diagrams. The complete 2000-2015 time series of South American CO_2 emissions (Indicator 9.4.1) is depicted using three different time series diagrams. **Top:** A line chart adding an emergent orientation cue. **Middle:** A stacked area chart relying on the visual variable size of the stacked areas much like a proportional symbol map or cartogram. **Bottom:** A sorted stream graph relying on size, but on the line thickness rather than polygon area like a numerical flow map. An added orientation visual cue is included in the sorted stream graph when countries change their relative ordinal ranking. Unnormalized absolute data are needed for the stacked area chart, whereas the line and stream graph can represent absolute or relative values.

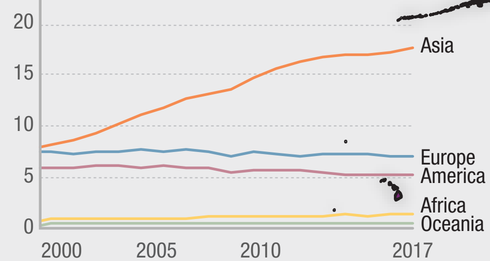


GOAL 9: BUILD RESILIENT INFRASTRUCTURE, PROMOTE SUSTAINABLE INDUSTRIALIZATION, & FOSTER INNOVATION

SDG Target 9.4
Upgrade infrastructure and retrofit industries to make them sustainable

▶ 32 billion tons of CO_2 were emitted globally in 2017

CO_2 Emissions (Billions of Tons)

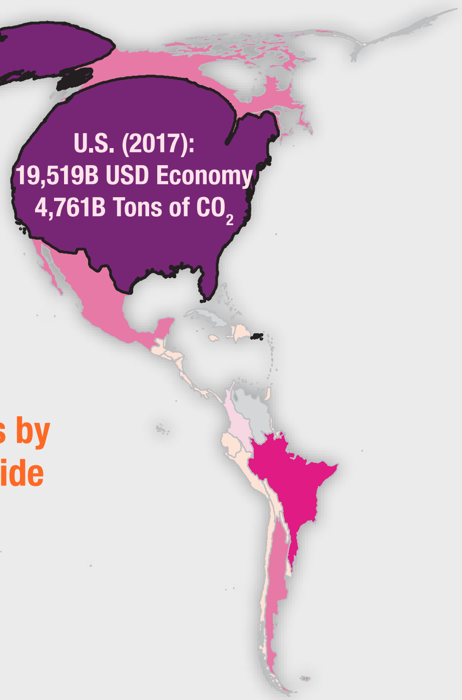


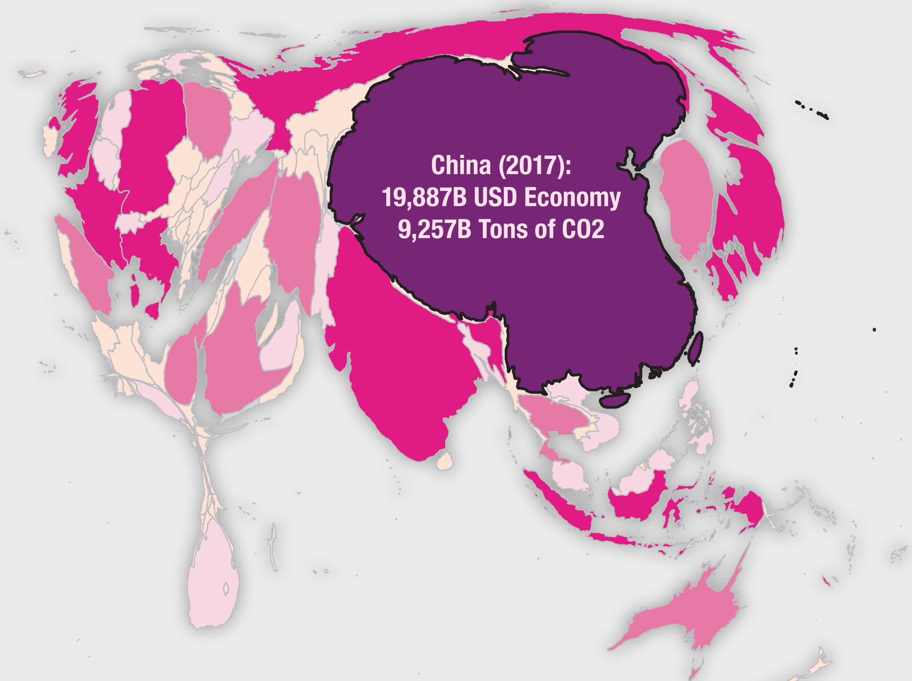
▶ The two largest national economies by GDP also emit the most CO_2 worldwide

Gross Domestic Product Purchasing Power Parity (Billions of USD; 2017)*

*Area resized by CO_2 emissions from fuel combustion (2017)

- $10,000–19,880B
- $2,500–10,000B
- $1,000–2,500B
- $500–1,000B
- $0.4–500B
- Missing data





◀ A Mongolian family uses solar panels to generate power for their ger, a traditional Mongolian tent, in Tarialan, Province of Uvs in Mongolia. The solar panels are sponsored by the United Nations Development Fund to empower herder groups to use clean energy. (Source: UN Photo/Ekinder Debebe, 2009)

▲ The map depicts Indicator 9.4.1 (2017) on CO_2 emissions in metric tons per chained dollars as a contiguous cartogram. Rather than mapping the normalized indicator as a choropleth map, the relative rate is reverted to the original absolute attributes and then mapped using two different visual variables: countries are scaled by total CO_2 emissions from fuel combustion (size) and then then shaded by gross domestic product (GDP) purchasing power parity (colour value).

The resulting bivariate cartogram visually normalizes GDP by CO_2 emissions, showing dramatic differences among regions. As temperatures rise an estimated 1.5°C by 2100, the cartogram reveals that the Global North has a disproportionate responsibility in reducing CO_2 emmissions through sustainable infrastructure and industries.

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

SECTION 4: MAP USE ENVIRONMENTS

4.1 Audiences

The audience describes the intended users of the map (see Section 2.1). In the past, the same static map served all audiences despite the diversity across map user and use contexts. Today, digital technology has transformed how maps reach their audience, as maps increasingly are interactive (see Section 4.3) and accessed over the internet (see Section 4.5) or on a mobile device (see Section 4.6). New map use environments mean that maps and geospatial data reach more people across the globe than ever before, needing to adapt to the specific backgrounds, interests, and needs of different audiences. Such individual differences should be understood before starting a project and considered throughout the map design process (see Section 2.2).

A first step in characterizing the audience is deciding between a general use case versus a specialist use case. The ***Cartography Cube*** framework organizes broad map use cases according to three axes: map users (the emphasis in this section), map use tasks, and map interactivity (Figure 4.1-1). For ***general users***—such as the public at large to promote awareness and action about the SDGs—present known information about the indicators following the map design recommendations outlined in prior book sections and implement constrained interactivity on digital devices. In contrast, enable ***specialist users***—such as cartographers, statisticians, and other affiliated stakeholders with the United Nations—to generate previously unknown insights about the indicators by interactively creating a wide number of alternative maps.

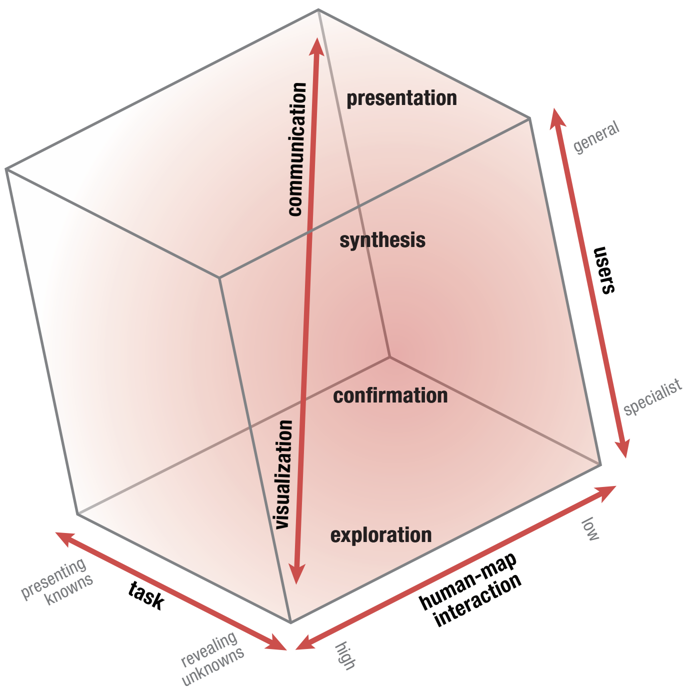


Figure 4.1-1: Cartography Cube. The Cartography Cube framework organizes broad map uses cases by three axes: map user, map use tasks, and map interactivity. Specialist audiences are small and trained to explore or confirm patterns in mapped datasets (see Section 4.10). These results are then synthesized into an explanation for visual presentation to general audiences that are wide and diverse (see Section 4.7).

Figure 4.1-2 (Opposite side): Individual differences. Map design and use is influenced by a range of individual differences in the intended audience, including accessibiliy, expertise, skills, and motivation, among others.

1. Accessibility: Ability to obtain and benefit from the map

[ ] **Participation:** Who is (and is not) included in the map conceptualization, design, evaluation, ownership, and use.
[ ] **Visual Impairment:** Limitations in visual ability such as low-sightedness, corrected vision, colour vision deficiency, and non-sightedness (see Section 4.2).
[ ] **Disability:** Limitations in other perceptual, cognitive, physical, or emotional faculties.
[ ] **Digital Divide:** Non-faculty limitations in digital access, such cost, access to computing and internet technologies, and interoperability across platforms and services.

2. Expertise: Learned knowledge enhancing abilities for using the map

[ ] **Education:** Formal study and training in map design and use as well as the subject area.
[ ] **Experience:** The amount of time working in map design and use as well as the subject area.
[ ] **Familiarity:** Self-reported understanding of map design and use as well as the subject area.

3. Skills: Specific knowledge areas for using the map acquired through expertise

[ ] **Literacy:** Skills in reading, writing, and speaking in a language or multiple languages, including unique character sets, familiarity with endonyms and exonyms (see Section 2.12), and translation among multiple languages.
[ ] **Numeracy:** Skills with reading, interpreting, and critically evaluating quantitative data, with specific emphasis for mapping on levels of measurement (see Section 1.4), normalization (see Section 1.7), and classification (see Section 1.9).
[ ] **Spatial Thinking:** Skills in reading, interpreting, and critically evaluating maps, specifically in using the map as a model representing more complex geographic phenomena and processes.
[ ] **Technology:** Skills with using and developing underlying interactive, web, and mobile technologies supporting the map use environment.

4. Motivation: The desire to use the map

[ ] **Interest:** Desire to use the map out of curiosity, entertainment, incentives, popularity, recommendation, self-improvement, or other interests.
[ ] **Need:** Desire to use the map out of necessity, often as part of work responsibilities or emergency events.

In practice, general versus specialist is an imperfect binary that misses the intersectional identities and local contexts of potential audiences. A ***needs assessment*** is a study recommended at the beginning of a mapping project to understand and better design for the intended user personas and use case scenarios (see Section 4.12). Often conducted as surveys, interviews, focus groups, or a combination therein, a needs assessment should collect background on the intended audience that might influence map use and therefore map design decisions (Figure 4.1-2) as well as their values, practices, and opinions about mapping needs and gaps with existing solutions.

While a useful framework for characterizing target users, the above list does not capture many important cultural, ethnic, geographic, political, religious, and sociodemographic considerations. At all times, seek to promote cross-cultural sensitivity and empower marginalized voices when mapping the SDG indicators.

4.2 Accessibility & Visual Impairment

Accessibility in cartography describes the ability to obtain and benefit from a map, with the goal of supporting the widest possible range of audiences (see Section 4.1). Accessibility requires cartographers to consider perceptual, cognitive, physical, and emotional disabilities as well as technical barriers that impact map use and, therefore, produce unequal access to maps and geospatial data. Accordingly, accessibility increasingly is described as ***inclusive design***, or designing for the most marginalized users first rather than an imagined "average" or "normal" audience. In most cases, supporting accessibility for specific audiences improves the experience for all audiences.

The United Nations Convention on the Rights of Persons with Disabilities and its Optional Protocol (A/RES/61/106) sets guidelines for the design of accessible maps and data products, particularly those distributed online. Recommendations for interactive, web, and mobile map design include the following: organize content with clear hierarchy and navigation, use concise and machine-readable text to support screen readers and multilingual translation, provide alternative text descriptions and video captions, update messaging for interactive maps to reflect the current map display, and support multimodal user input (e.g., speech or eye-recognition).

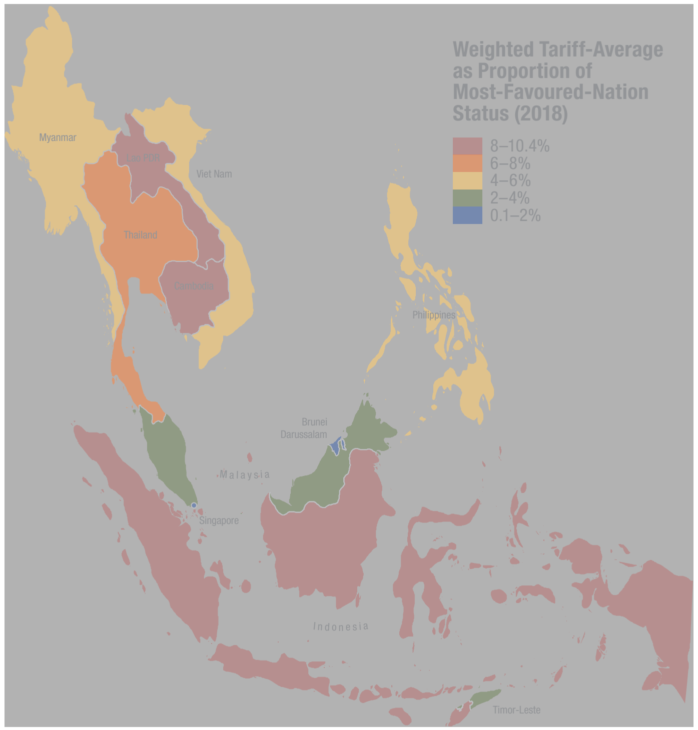
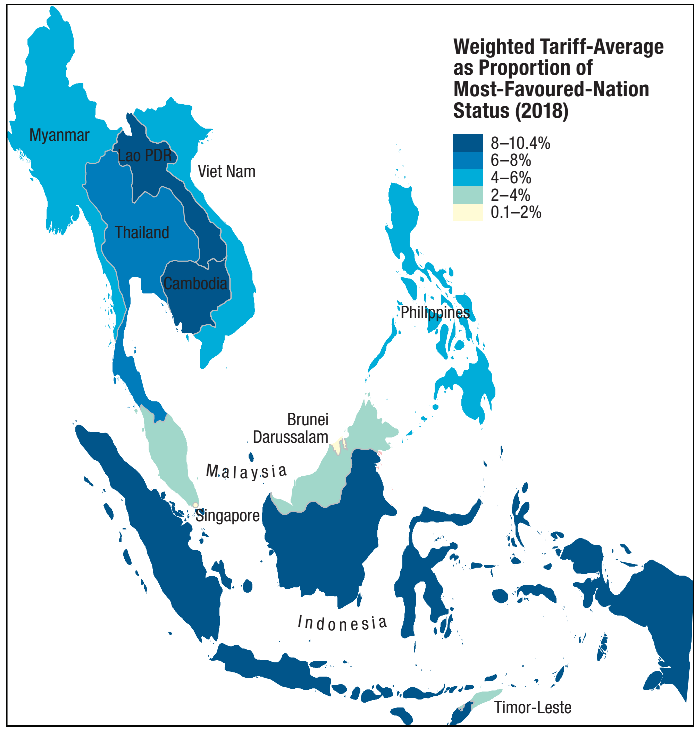


Figure 4.2-1: Suboptimal design for visual impairment. Indicator 17.10.1 (2018) on the weighted tariff-average as a proportion of the most-favoured-nation status is mapped as a choropleth map. The spectral colour scheme causes confusion between the green class and other choropleth colours for those with colour vision deficiency. Reading the choropleth is further impaired by the grey background, creating poor contrast between some choropleth colours and the background. The yellow middle-class also inappropriately rises to figure. Finally, the 4-point, light grey labels are below resolution thresholds for the print medium of the book. While discernible for some, this design excludes many individuals on the margins.

Visual impairment, or limitations in visual abilities, is treated as a special case of disability in cartography given reliance on the "visual language" (see Section 2.9). Visual impairment includes individuals who are low-sighted and require corrected vision, are colour vision deficient (informally referred to as "colour-blind"), or are non-sighted (i.e., blind). To create visually accessible maps, use a contrast ratio—or difference in colour value—of at least 4.5:1 between figure and ground (see Section 2.13), with 7:1 often used for text against background. Further, set a minimum of 6-point and 10-point type sizes (see Section 2.11) for print versus screen, respectively, given their differences in display resolution. Finally, avoid relying on colour hue combinations that are indiscernible by individuals with colour vision deficiency, such as red and green, by choosing colour-safe schemes or redundantly encoding information with additional, non-colour visual variables. ColorBrewer.org provides colour schemes for maps that work for the most common cases of colour vision deficiency (see Section 2.10).

Tactile maps and sound maps are non-visual alternatives supporting the visually impaired and are increasingly viable for accessibility through advances in 3D printing technology and handheld mobile devices.

Figure 4.2-2: Improved design for visual impairment. Indicator 17.10.1 (2018) is remapped following inclusive design guidelines to account for visual impairment. The spectral scheme is replaced with a colour-safe sequential scheme supporting those with colour vision deficiency. The white background allows for sufficient visual contrast in all choropleth colours, with a logical increase in colour value matching a similar increase in attribute values. The 6.5-point black labels are sufficient for print but may require zooming when viewed digitally. While the redesign is more inclusive for many visual impairments, it remains inaccessible for non-sighted audiences and therefore requires a non-visual alternative to promote inclusive design.



4.3 Interactive Maps

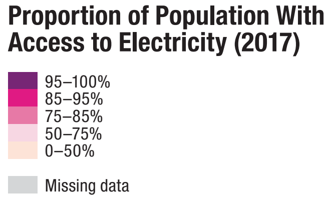
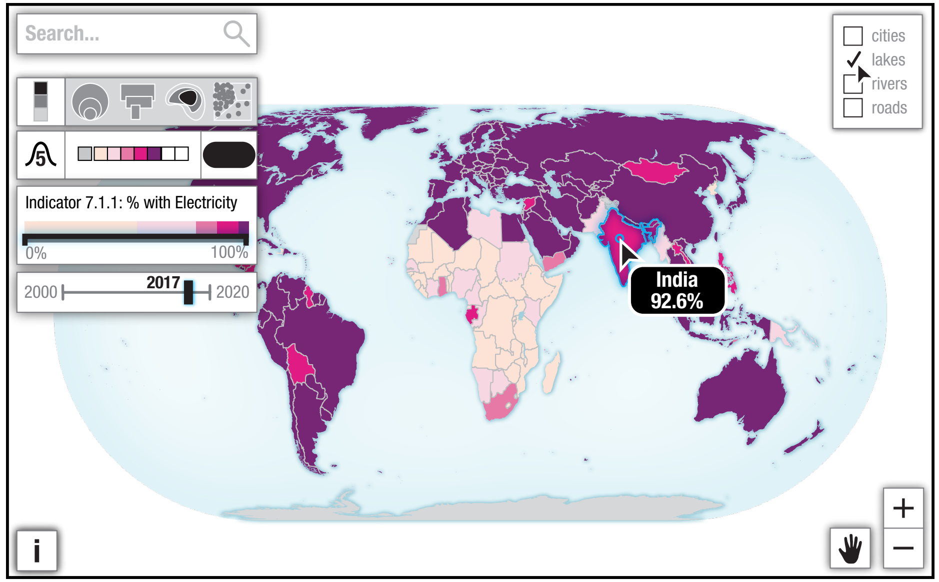


Figure 4.3-1 (Opposite side): Recommendations for non-mobile cartographic interface design. Indicator 7.1.1 (2017) on the proportion of population with access to electricity is depicted in a hypothetical interactive map following non-mobile cartographic interface design recommendations. The layout maximizes screen real estate for the map, fixing direct manipulation widgets to the corners. The form fill-in search box provides a clear entry point at the top-left. Beneath the search form are interface controls that configure the map view. Controls that contextualize the map are placed at the right side of the layout. Icons provide visual affordances for using the direct manipulation controls and suggestive "Search..." text provides an affordance for the form fill-in interface. A cursor and blue highlighting are provided as visual feedback for the location of the hypothetical interaction, here, retrieval of the value for India. A legend is provided outside of the hypothetical interface for context.



Maps increasingly are used in a digital environment that is highly interactive. An ***interaction*** is like a conversation, with digital computing technology mediating a series of question-and-answer sequences between the user and map. Interaction empowers the audience to request new maps in real time, adapting the map display based on their individual needs and differences (see Section 4.1).

The possibility of interactivity has transformed cartography in at least two ways. First, interactivity means that the map is no longer a static snapshot in time that quickly grows out-of-date. Instead, the map is an interface to a dynamic spatial database that can be updated regularly over time, as with the indicator datasets. Second, interactivity shifts the relationship between cartographer and audience; the audience of map *users* is now also the audience of map *makers*, redesigning their own maps iteratively through interaction.

An ***interface*** is a digital tool used to manipulate onscreen elements. Given their visual nature, cartographic interfaces rely heavily on ***direct manipulation*** or the probing, dragging, or adjusting of graphic user interfaces (GUIs) through clicking (for non-mobile) or tapping (for mobile; see Section 4.6). Users can directly manipulate: (1) individual map features (common for detail retrieval), (2) the map as a whole (e.g., pan, zoom, rotate), (3) the map legend (e.g., filter, resymbolize), (4) a linked view (e.g., reexpress, filter, retrieve), or (5) custom widgets such as checkboxes or slider bars (e.g., filter, overlay, sequence) (**Figure 4.3-1**). Other visual interface styles include dropdown ***menu selection*** (common for filter) and ***form fill-in*** input (common for search). Section 4.4 discusses interaction operators (e.g., pan, zoom, retrieve) in more detail.

The interactive map should maximize the ***screen real estate*** (i.e., proportion of the layout) dedicated to the map rather than the interface controls. The interactive map also should have a clear ***entry point***, making the user's first click or tap obvious. The layout of interface controls then should suggest their relative importance, separating between controls that ***configure*** the map before use and those that add ***context*** after initial use of the map.

While interfaces provide the controls for manipulating the map, users experience interactions as a "conversation" through visual affordances and visual feedback. ***Visual affordances*** are signals to the user about how to interact with the provided controls, such as icons for direct manipulation, a dropdown arrow for menu selection controls, and concise textual descriptions for form fill-in input. In contrast, ***visual feedback*** are signals about what happened as a result of the interaction and may include loading progress menus, updated messaging about the current map display, and highlighting of changes in the map. A cursor and blue highlighting are used as visual feedback for figures in this section to indicate how and where users have interacted with the hypothetical interface depicted in the figure. Visual affordances and visual feedback should be designed consistently across all interfaces and, thus, need to be coordinate with the map symbolization, as affordances and feedback often rely on one or several visual variables.

When applied to the SDG indicators, interactive mapping dashboards help specialist users explore multiple indicator datasets to generate new insights about global conditions and subsequently evaluate alternative practices to reduce global inequality (see Section 4.9). Even for presentation to general audiences, interaction allows users to customize the display and work through the maps and diagrams at their own pace, such as in the context of storytelling (see Section 4.7).

4.4 Interaction Operators

An ***interaction operator*** describes generic interactive functionality that enables users to manipulate the map display (**Figure 4.4-1**). As with symbolization and the visual variables (see Section 2.9), interaction operators form the basic building blocks of interactive maps. Every operator can be implemented using any interface style (see Section 4.3), so it often is more helpful to consider generic operators rather than their graphic user interfaces when planning an interactive map design.

Some operators change the map design itself, allowing users to ***reexpress*** to a different thematic map type (see Section 3.1) or diagram (see Section 3.10) using the same data, ***sequence*** through an ordered set of maps as with an animation (see Section 4.8), ***overlay*** layers atop the basemap and underlay different basemaps, or ***resymbolize*** within a given thematic map type such as changing the classification (see Section 1.9) or colour scheme (see Section 2.10).

Other operators change the user's viewpoint to the map, allowing the user to ***pan*** away from the projection centring (see Section 2.5), ***zoom*** to a more local or global cartographic scale (see Section 2.6), ***reproject*** to change the map projection distortions (including rotate from "north" as "up" for mobile maps; see Section 4.6), and ***arrange*** the layout of maps and diagrams (see Section 2.13).

A final set of operators change the data content in the map, allowing the user to ***search*** for specific map features of interest, ***filter*** the depicted map features by given criteria, ***retrieve*** additional details on-demand for specific map features, or ***calculate*** new information from the map.

As shown in **Figure 4.1-1**, the number of implemented operators depends on the audience and their goals. Maps for exploration may contain many or all of the interaction operators. Exploratory interactive maps coordinate interactions across multiple views, with particular emphasis on the reexpress, zoom, filter, and retrieve operators (see Section 4.10). For presentation, constrain interaction and provide a form fill-in search box to locate previously known map features of interest. General audiences also now expect pan, zoom, and retrieve by convention for web maps.

Most maps of the indicators do not require complex interactivity, and indeed many interaction operators may lead to misleading maps when implemented without intention. Only implement a given interaction operator when it clearly supports an identified user need.

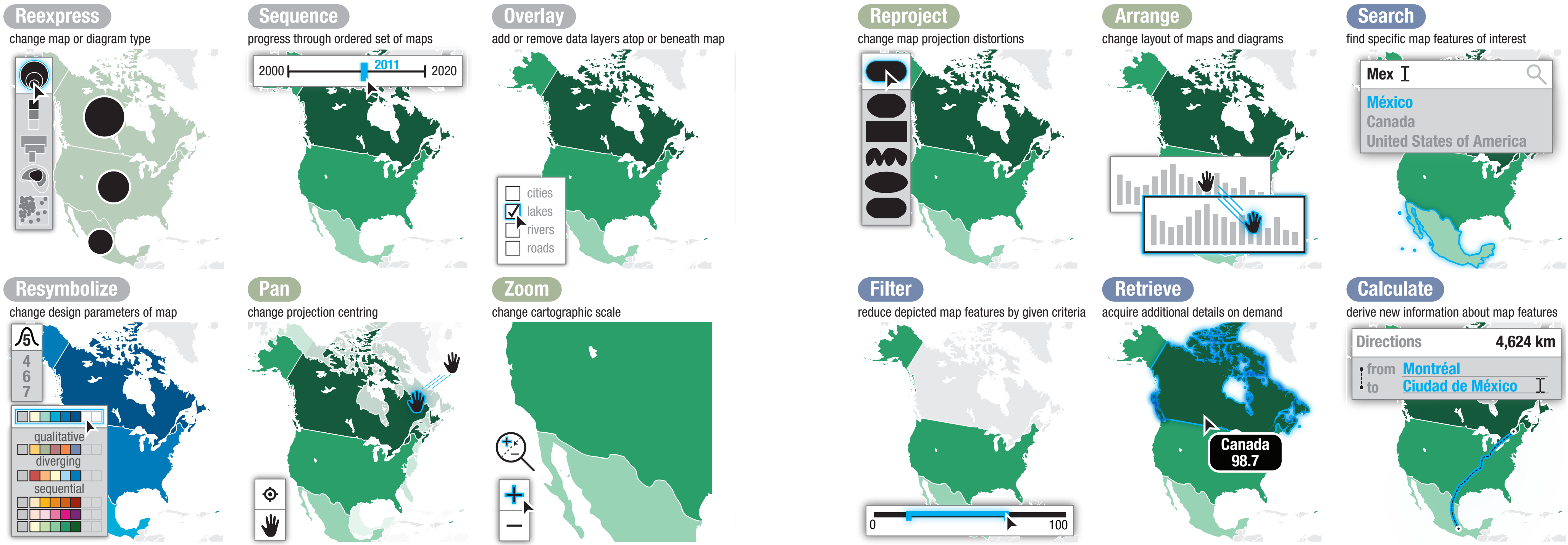


Figure 4.4-1: Interaction operators. Colouring depicts the result of the interaction operator, with operators varying by how they change the map design, the audience perspective, or the mapped content.

4.5 Web Maps

Maps can reach such wide and diverse audiences because of the internet. The ***internet*** refers to a series of interconnected computer networks that facilitate the transfer of files. The ***World Wide Web***, byname the ***web***, refers to the interconnected documents (i.e., web pages including ***web maps***) shared over the internet and rendered in a web browser. The internet facilitates both data collection, such as the crowdsourced OpenStreetMap project, and data dissemination, as with communication of the SDG indicator datasets.

While there were many precursors, the initial release of Google Maps in 2005 was a watershed moment in web map design. Google Maps popularized tile-based web maps that support the experience of a "map of everywhere" by slicing maps designed at 20 different cartographic scales (see Section 2.6) into 256 x 256 pixel (i.e., 8-bit) image tiles, and then loading a small fraction of those tiles into the browser based on user interaction (i.e., only those tiles at and around the current view). Tile-based maps, now common today (Figure 4.5-1), are referred to as ***slippy web maps*** for their inclusion of panning and zooming for interactively browsing the multiscale tileset (see Section 4.4).

The frameworks and technologies used to develop and host web maps are broad, often requiring compilation of multiple, specialized tools and techniques referred to as a ***web stack*** (Figure 4.5-2). Most web maps today are built upon open web standards (see Section 4.13), which include ***HTML*** (Hypertext Markup Language) used to structure the content of a web document, ***CSS*** (Cascading Style Sheets) used to style this content, and ***JavaScript***, a scripting language used to add interactive behaviours to elements in the document. Increasingly, web maps make use of the ***JSON*** (JavaScript Object Notation) file format (with GeoJSON and TopoJSON geospatial variants), drawing these data as ***SVG*** (scalable vector graphics) atop basemap tilesets.

Figure 4.5-1: The United Nations Clear Map. The United Nations tile-based web map, entitled "Clear Map," can be embedded within websites to enable interactive panning and zooming across the world. The depicted example uses Clear Map for basemap reference context in the United Nations Peacekeeping website: https://peacekeeping.un.org/en. The resulting web map, developed using Leaflet.js as the client-side technology, adds interactive marker icons atop Clear Map tiles that locate current United Nations peacekeeping operations.

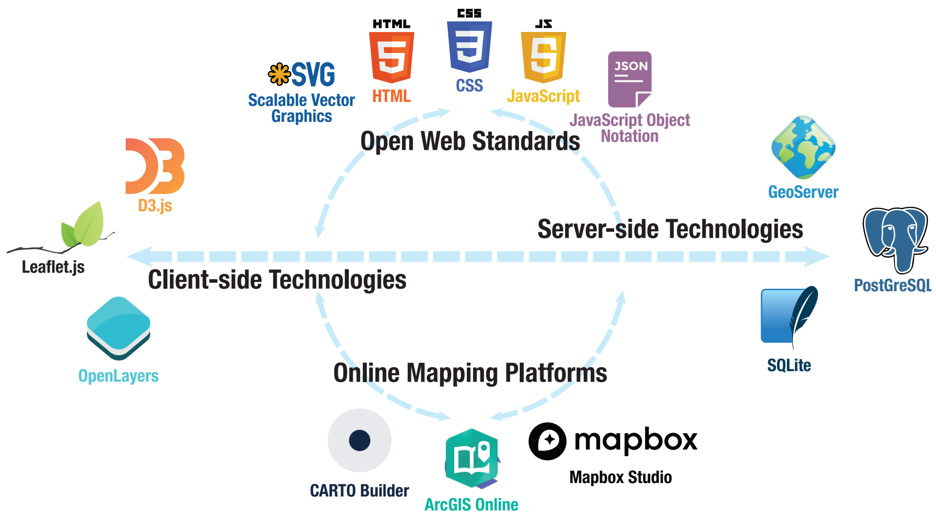


Figure 4.5-2: Full stack web cartography. Web technologies are diverse and ever-changing, making any overview far from comprehensive. The figure instead is meant to give a sense of general differences between client-side and server-side web map technologies as well as open web standards and proprietary online mapping platforms supporting these technologies to help understand and evaluate the technological web cartography landscape as it evolves.

The open web often is described as a "platform" that enables interactive exchange between ***server-side technologies*** used to store data, including geospatial datasets, and ***client-side technologies*** used to render this data in the browser for viewing and manipulation by the user, including maps and diagrams. Common open source server-side technologies for web mapping include GeoServer, PostgreSQL, and SQLite and common open source client-side technologies for web mapping include D3.js, Leaflet.js, and OpenLayers.js. Notably, there is a growing number of proprietary web mapping services that simplify full stack web mapping through a user-friendly interface, including ArcGIS Online, Carto Builder, and Mapbox Studio.

While web mapping often is considered ubiquitous, a ***digital divide*** still remains between those that have access to the internet and its underlying computer technology and those that do not (see Section 4.1). SDG 9 on Industry, Innovation, and Infrastructure sets a target to provide universal and affordable access to the internet and, thus, universal and affordable access to web maps.

4.6 Mobile Maps & Responsive Design

Maps are among the most common applications accessed on ***mobile devices***, or handheld portable computing systems such as smartphones, smartwatches, and tablets. ***Mobile-first design*** for cartography optimizes maps for the technological constraints of mobile devices, which include small screen displays, reduced processing power and memory capacity, unreliable connectivity and reduced bandwidth, limited battery life, and multitouch interaction. ***Responsive design*** describes the design logic for changing the layout, content, and styling of digital maps between mobile and non-mobile devices (e.g., a desktop computer).

While the focus during design often is on the constraints of mobile devices, mobile maps have one major advantage over other maps: they can represent and customize the display to the user's changing location. Mobile devices contain ***GPS*** (Global Positioning System) and other spatial sensors (e.g., barometers, gyroscopes) that capture the user's location in three-dimensions. They also sense the direction the user is currently facing. Such ***location-based services*** can be used to centre an SDG map on the user's location, helping build geographic understanding about inequities, interdependencies, and alternatives from local to global geographic scales (see Section 2.6).

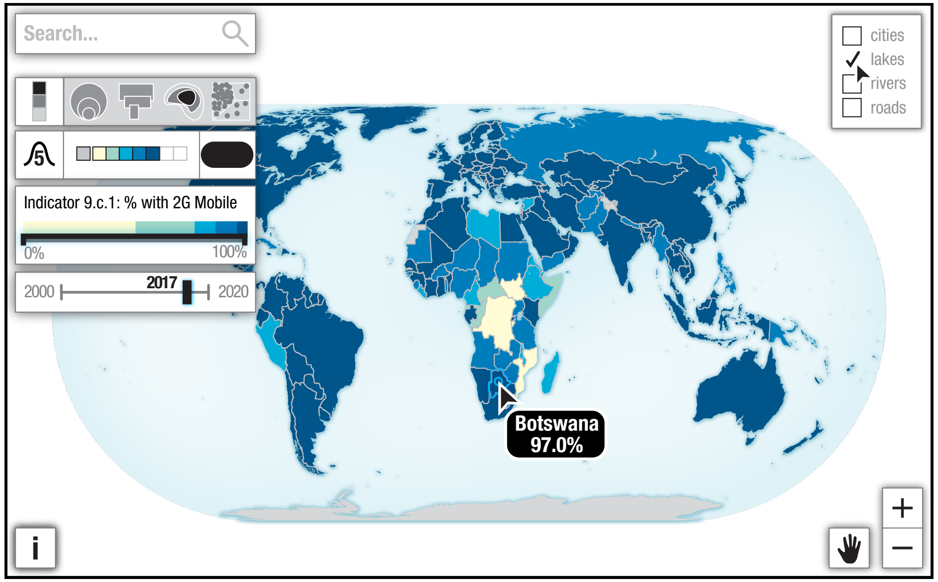
As with web mapping, SDG 9 on Industry, Innovation, and Infrastructure sets a target to provide universal and affordable access to mobile communications technology and, therefore, universal and affordable access to mobile maps.

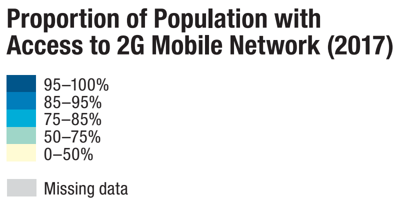
Mobile-first and responsive design recommendations are tied to specific decisions in the cartographic design process and, thus, adapt guidelines from prior sections of this book (Figure 4.6-1). For mobile-first projections (see Section 2.4 and Section 2.5), centre the map on the user's location, updating while moving. Also support the reproject operator (see Section 4.4) to rotate the map so that "forward" rather than "north" is "up".

Consider a larger default cartographic scale for mobile viewing (see Section 2.6), situating users in their local context first and then requiring them to zoom-out for global comparison. Simplify the linework to the extent possible for mobile-first generalization (see Section 2.7) to improve accessibility on limited bandwidth and data plans.

Increase brightness and contrast for symbols at the top of the visual hierarchy (see Section 2.13) to account for variable environmental conditions. Also consider darker colour palettes and basemaps to reduce impact on mobile battery life.

Finally, support touch-based direct manipulation for mobile-first interaction (see Section 4.3) such as single-tap to retrieve, pinch or double-tap to zoom, grab-and-drag to pan, and finger-twist to rotate. Place configuration controls in a small ribbon along the bottom of the layout for one-handed, thumb-based interactions. When bottom controls are activated, open a dialog window with advanced widgets that fully covers the map. Place context controls away from the bottom, encouraging direct manipulation of the map itself.





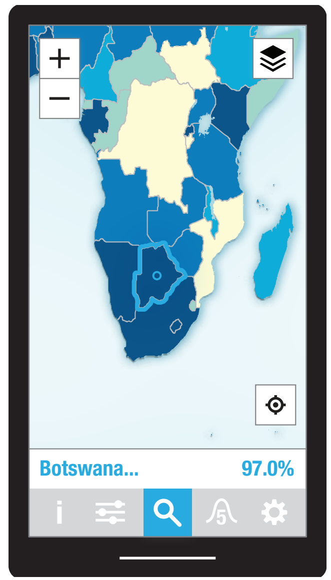


Figure 4.6-1: Recommendations for responsive cartographic representation and interface design. Indicator 9.c.1 (2017) on the proportion of population covered by a 2G mobile network is mapped for both non-mobile and mobile viewing following recommendations for responsive cartographic design. **Left (Opposite side):** The non-mobile design, similar to Figure 4.3-1. **(Right):** The mobile design. The mobile design uses a larger default cartographic scale for local context and organizes the configuration interface controls into a bottom menu for thumb-based interaction. Context controls are positioned away from the thumb position, with the map itself supporting touch-based interaction such as the hypothetical single finger tap in the example to retrieve details about Botswana. The hand affordance for the pan control is replaced with a crosshairs to recentre on the user's location.

4.7 Storytelling with Maps

Storytelling is a method of documenting or explaining a sequence of events and, thus, is an important social and cultural tool for sharing and remembering individual experiences. From journalism to science communication, there is growing interest in how maps can organize and enhance storytelling. Accordingly, map-based storytelling offers a valuable opportunity to engage both Member States and individual citizens in communicating the aims of the SDGs. A "story map" could be a key advocacy communication tool for the SDGs across partners.

Maps are inherently two-dimensional (see Section 1.3), but a story map differs from other maps by leading the audience through a primarily one-dimensional, linear narrative. Here, ***story*** describes information about specific events, places, and people while ***narrative*** describes the structure and presentation of this content to shape the story's meaning. The broadest definition of a ***story map***, therefore, is any cartographic representation that exhibits narrative elements. ***Visual storytelling*** refers to stories communicated through maps, graphics, images, and videos along with other forms of oral, written, and audio storytelling.

While often adapted, the ***three-act narrative*** provides a useful baseline for designing a visual story (Figure 4.7-1). The narrative begins with the ***set-up***, introducing background context such as the setting and key characters: for example, presenting and comparing different countries or SDG regional groupings. The narrative proceeds to the ***conflict***, emphasizing the key problem motivating the story, which might be individual maps explaining different dimensions of an SDG. The narrative concludes with the ***resolution***, reaching the climactic issue facing the characters and presenting one or several resolutions, such as recommendations for action on the SDGs.

In practice, there are a number of ways for enforcing linear continuity across a narrative arc, described as visual storytelling ***genres*** (Figure 4.7-2). ***Static visual stories*** use layout partitioning and annotation to advance the linear narrative, ***longform infographics*** use vertical reading and browser scrolling, ***dynamic slideshows*** use an ordered set of slides, ***narrated animations*** use the progression of display time (see Section 4.8), ***multimedia visual experiences*** use anchor tags and hyperlinking, ***personalized story maps*** use the order of user contributions to the map (older presented first), and visual story ***compilations*** use the order of unfolding events (newer presented first).

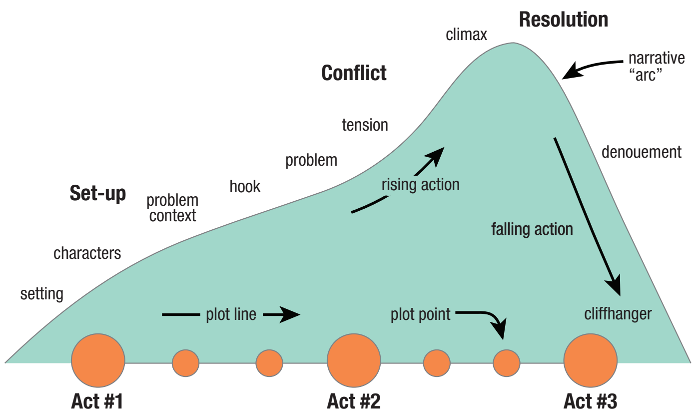
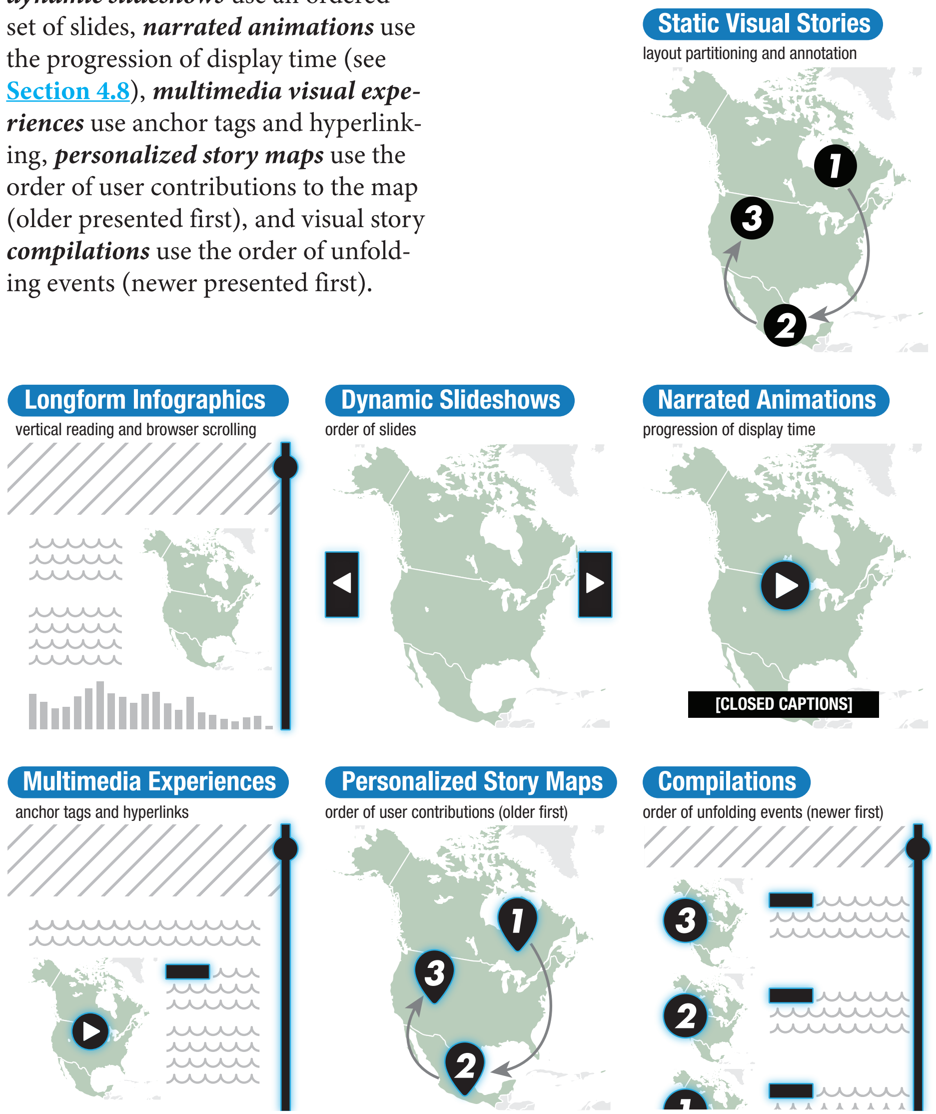


Figure 4.7-1: Three-act narrative. While many narrative structures exist, beginning with a traditional three-act narrative helps to plan and organize content for a visual story or story map.

Figure 4.7-2: Visual storytelling genres. The elements highlighted in blue indicate the typical interactive features used to enforce linearity for the genre. Static visual stories do not require interactive map use environments.



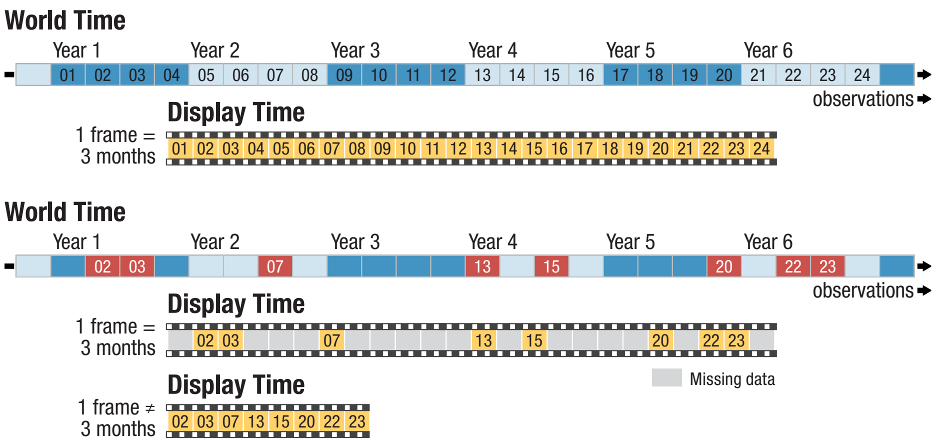
4.8 Animation

Animation uses digital system time to update the map display (in contrast to user interaction; see Section 4.3). Conceptually, an animation consists of an ordered series of ***frames*** played in sequence to give the audience an appearance of movement and change. Technologically, these frames can be a series of preprocessed static images (i.e., a frame in film) or, more commonly, dynamic graphic updates produced computationally.

Two kinds of animations are useful for mapping the SDG indicators: temporal and non-temporal. ***Temporal animation*** represents real-world temporal data with display time, producing a ***temporal scale*** (e.g., 1 second = 10 years) similar to a cartographic scale for location data (e.g., 1 cm = 10 km; see Section 2.6). Temporal animation is good for depicting changes and trends over time (see Section 3.9), helping to gain insight into the underlying geographic processes driving patterns in the SDG indicator datasets. Accordingly, temporal animation provides a congruent representation to monitor progress and persistent gaps in the global social, economic, and environmental challenges encapsulated by the SDGs. Temporal animations typically represent absolute rather than relative time, although both are possible, and also can represent linear or cyclical time (see Section 1.5).

Despite their advantages, temporal animations have some limitations. Because animation conceptually combines a large number of map frames together in sequence, they are much more visually complex than a static representation of time. As a result, the audience often misses a large amount of the changes to the display, a phenomenon known as ***change blindness***. Change blindness also results in bias towards the first and last frame in the animation, with less information retained in between. Finally, missing data in a time series is common, which can distort the temporal scale if display gaps are not maintained in animation (**Figure 4.8-1**)

Figure 4.8-1: Temporal scale. Temporal scale describes the relationship between display time and real-world time. **Top:** Regular data captures four times a year result in a temporal scale of one frame for three real-world months for the animation. **Bottom:** Missing observations require display gaps to maintain the temporal scale.



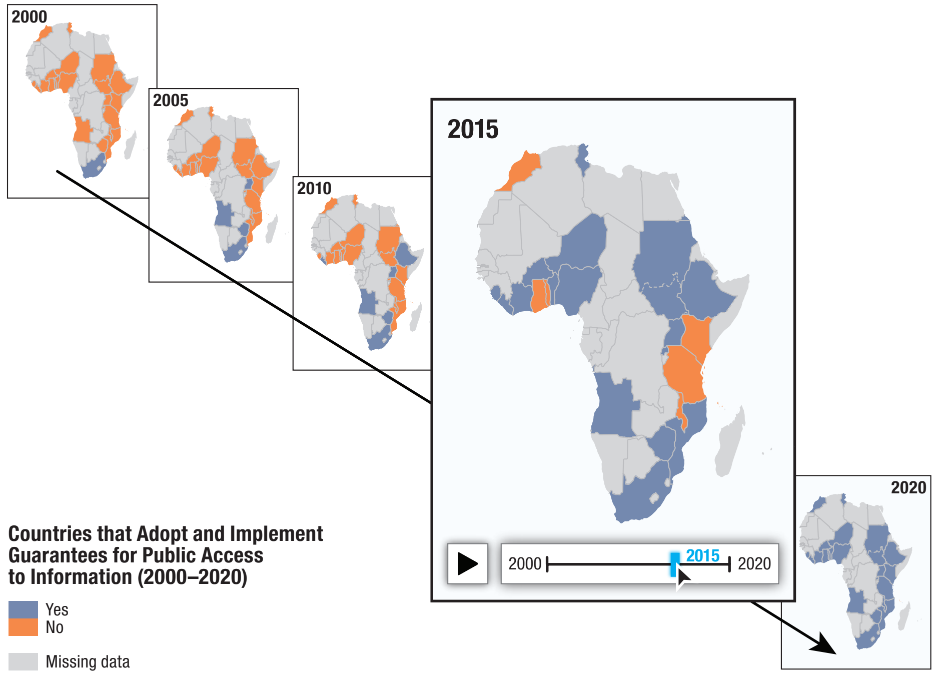


Figure 4.8-2: Interacting with time. Indicator 16.10.2 (2000–2020; depicting countries that have adopted and implemented guarantees for public access to information is animated over five-year intervals. The user can play the animation passively or interact with the sequence control to show a specific year.

The relationship between real-world and display time in temporal animation should be communicated through a temporal legend, such as a timeline or clock. To reduce change blindness, the temporal legend often is interactive, supporting the sequence operator (see Section 4.4), and is paired with additional playback controls to allow users to pause and step backwards and forwards (**Figure 4.8-2**).

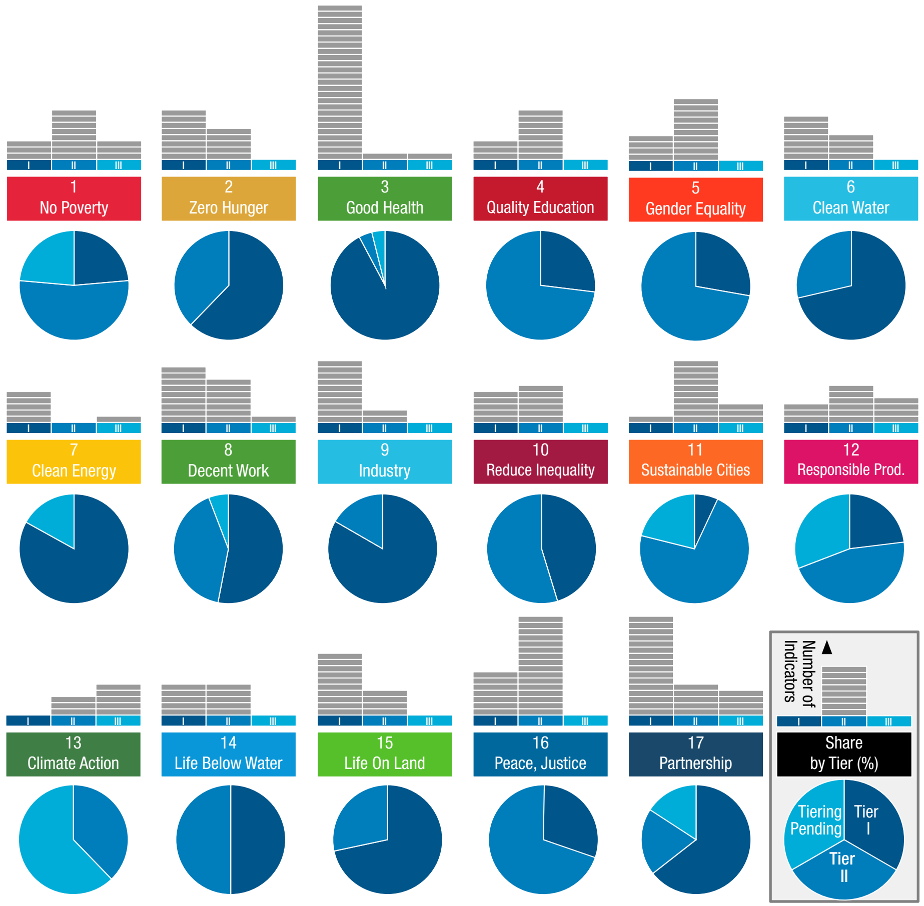
In contrast, ***non-temporal animation*** orders frames to facilitate understanding of the map, often highlighting specific map features or progressively building the map one data class at a time to highlight low or high values. Non-temporal animations include the narrated animation storytelling genre (see Section 4.7), with frames ordered according to a linear narrative and ***fly-throughs*** that change the viewpoint perspective, which work particularly well for representing 3D terrain.

4.9 Dashboards

A ***dashboard*** provides a visual summary of data, often displayed as multiple maps and diagrams of different locations, attributes, or time periods on a single screen. There are three categories of dashboards in practice: strategic, analytical, and operational.

A ***strategic dashboard*** provides an overview of key data parameters that policy and decision-makers need to measure and monitor, such as the SDGs and their indicators. For instance, strategic dashboards of SDG indicators could be on display at the United Nations Headquarters or made available to leadership in Member States as a backdrop to support planning and deliberation. The **Figure 4.9-1** dashboard shows the tier status for

Figure 4.9-1: Strategic dashboard. A strategic dashboard to monitor progress toward Tier I level indicators. The bar charts display the absolute number of indicators in Tier I, Tier II, and Tiering Pending. The pie charts show the relative status of indicators across tiers.



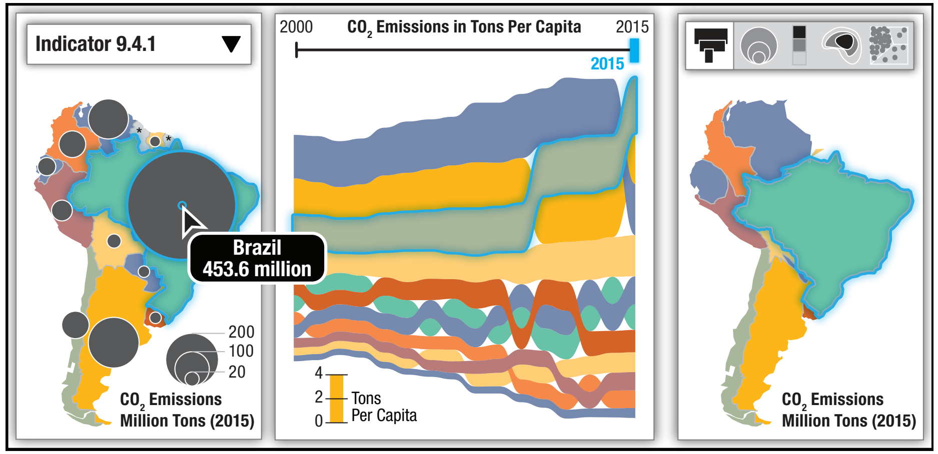


Figure 4.9-2: Analytical dashboard. Indicator 9.4.1 on CO_2 emissions is shown in an analytical dashboard containing a proportional symbol map (2015; millions of tons), stream graph (2000–2015; tons per capita), and cartogram (2015; millions of tons). The retrieve operator is coordinated across views to highlight the same data element (Brazil).

each SDG indicator in both absolute (bar graphs) and relative (pie charts) representations, providing a visual overview of the current state of methodological consistency and global data availability for the SDG indicators (see Section 1.6). Strategic dashboards summarize past and current status of the respective targets, and often do not require real-time data streams or interactivity.

In contrast, an ***analytical dashboard*** contains more extensive information and interactive functionality for generating and evaluating previously unknown insights into patterns, trends, and anomalies across a range of datasets. For the SDG indicators, analytical dashboards might be employed in regional and national laboratories or university campuses where policy makers and scientists work together to discover and test new solutions to global problems.

The **Figure 4-9.2** analytical dashboard links together a proportional symbol map, a stream graph, and a cartogram, supporting multiple perspectives on Indicator 9.4.1. Coordinated interaction across these multiple views is essential to support open-ended exploration and in-depth analysis (see Section 4.10).

Finally, an ***operational dashboard*** uses relatively simple maps and diagrams depicting real-time data streams and often provides alerts when thresholds are surpassed, requiring urgent response. Interactivity may be supported to retrieve additional information, but the interface typically is less complex for operational dashboards than that in analytical dashboards (see Section 4.4). Operational dashboards are not recommended for the SDG indicators given the slower speed at which indicator datasets are updated.

4.10 Exploratory Cartography

Exploration describes the specialized use of interactive maps and diagrams to generate previously unknown insights into geographic phenomena and processes. Exploratory cartography stimulates visual thinking, allowing the user to create new maps and diagrams as they reason about depicted patterns, trends, and anomalies. For the SDGs, the outcome of exploration is new hypotheses about and potential solutions for the broad social, economic, and environmental challenges facing our world.

Exploration is a fundamentally different use case for maps and diagrams than the traditional focus in cartography on presentation (see Section 4.1). For ***presentation***, the primary goal is effective and efficient visual communication from cartographer to wider audience following the cartographic design recommendations outlined in the first three sections of this book and, thus, often results in a single map outcome. For exploration, users are encouraged to violate many of these conventions, as it is unknown which alternative view of the data might spontaneously generate new insight.

Exploration typically fits a specialist rather than a general audience, as those less familiar with the mapped topic may obtain an incorrect impression without requisite training and background context. A storytelling approach may overcome this limitation, both presenting a narrative while including an exploratory interactive map at the beginning and ending of the story (see Section 4.7).

Exploration is enhanced by the ***coordination*** of interaction across multiple maps and diagrams, with an interaction operator applied in one view also applied to all others. For instance, when retrieving details from a map feature in one view, the same feature should be highlighted visually in all other views to enable comparison.

A common information-seeking strategy for exploration uses different sets of interaction operators across three stages (see Section 4.4). First reexpress the data to create an overview or a set of coordinated overviews (**Figure 4.10-1**). This first stage may also include sequencing across a time series to view trends in the overview or overlaying additional context to interpret the overview. Then, zoom and filter the overview based on observed patterns to narrow into a subset of previously unknown map features (**Figure 4.10-2**), perhaps also panning or resymbolizing to clarify the focused view. Finally retrieve details on-demand about map features of interest (**Figure 4.10-3**), which may include calculating additional statistics using the retrieved data.

Analytical dashboards (see Section 4.9) combine exploratory interaction with advanced statistical techniques to facilitate ***analysis***, or the confirmation of hypotheses generated during exploration. Specifically, ***geovisual analytics*** describes the use of visual interfaces to computational processes in support of analysis in addition to exploration. Some dashboards enable ***synthesis*** of evidence and findings to support subsequent presentation for visual communication, spanning all four map use cases introduced in **Figure 4.1-1**.

Death Rate Due to Road Traffic Injuries (Per 100,000; 2016)

24–35.9
16–24
12–16
8–12
0–8

Missing data

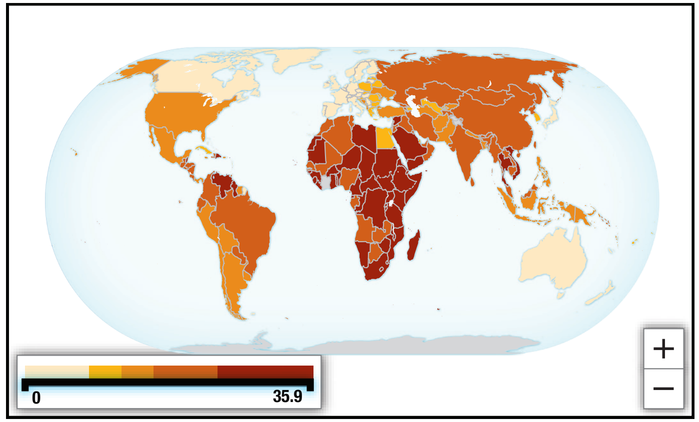


Figure 4.10-1: Overview first. Users first are presented with or reexpress to an overview map of Indicator 3.6.1 (2016) on the death rate due to road traffic injuries per 100,000 inhabitants. A legend is provided outside of the hypothetical interface for context.

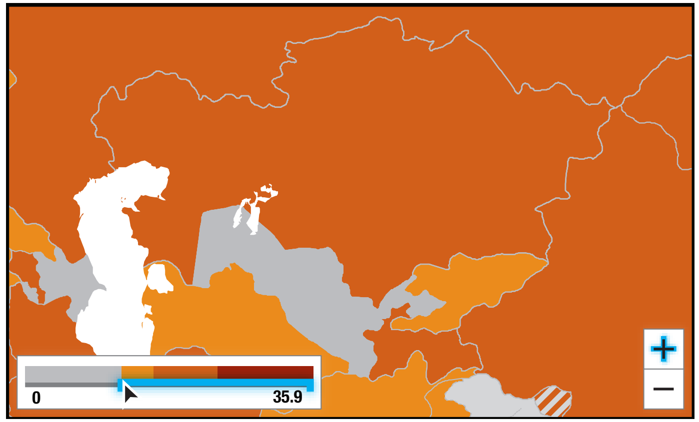


Figure 4.10-2: Zoom and filter. Users then interactively zoom and filter the display to narrow investigation into a subset of map features. Here, the user has zoomed into Central Asia to view specific country values and filtered the bottom two classes from the map.

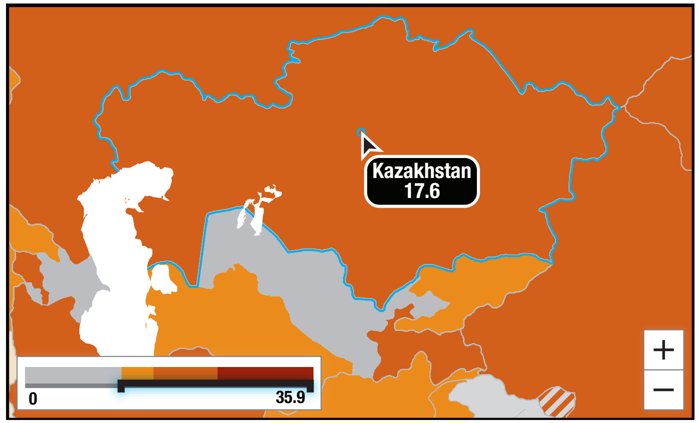


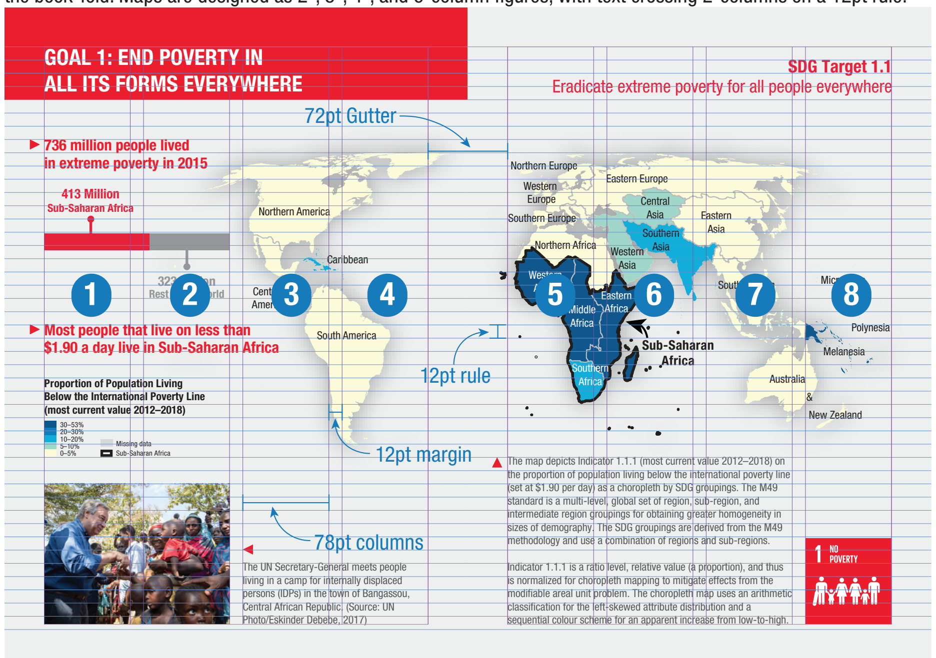
Figure 4.10-3: Details on-demand. Finally, users can retrieve details on-demand about a specific map feature of interest. Users may then reexpress to a new overview, repeating the process. This information-seeking strategy of overview first, zoom and filter, then details on-demand facilitates exploration through voluminous geospatial datasets and complex map representations in interactive map use environments.

4.11 Atlases

An ***atlas*** is an intentional sequence of maps, text, and other graphic elements depicting different dimensions of geographic phenomena and processes. Many atlases focus into a specific subject, such as a particular thematic domain (*who/what*), time period (*when*), or location (*where*) (see Section 2.1). Atlases serve a variety of purposes, including general reference or geographic education as well as awareness and outreach. An atlas's editorial board contributes to its authority, especially for national atlases.

Atlas design depends heavily on the presentation medium. Traditional atlases are published as printed books. Here, each map is arranged as a two-page layout for folded printing, called a ***spread***, with a vertical gap, or ***gutter***, in the centre to account for the book-fold (**Figure 4.11-1**). Projections should be centred so that the gutter slices the map in negative space (see Section 2.5), such as the ocean for a world map on land-based SDG indicators. The atlas spread also should be organized into a regular ***grid*** of columns and/or rows, such as the 8-column grid used in this smaller A5-size book or a 12-column grid for larger print publications and responsive design for mobile maps (see Section 4.6). Using a grid improves the layout and balance of maps, text, and negative space in more complex atlas spreads (see Section 2.13).

Figure 4.11-1: Traditional atlas spread. The 8-column grid used in this book is shown beneath the Section 1.3 two-page spread. Each column is 78pt with a 12pt margin, with a 72pt gutter expanding the Atlantic Ocean to account for the book-fold. Maps are designed as 2-, 3-, 4-, and 6-column figures, with text crossing 2-columns on a 12pt rule.



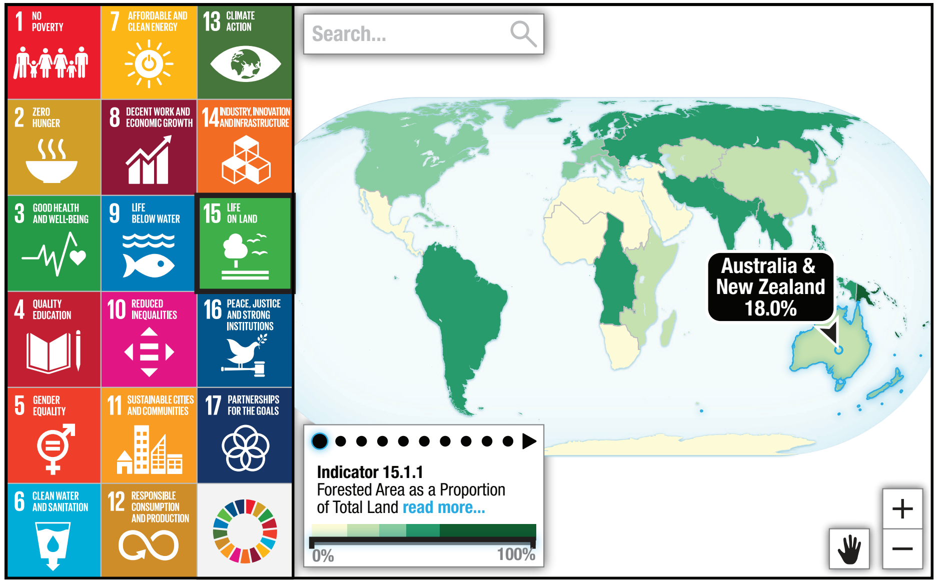


Figure 4.11-2: Interactive atlas. Like a traditional atlas, an interactive atlas organizes datasets and maps by themes, such as individual SDG indicators. The audience first selects an SDG (here, SDG 15 Life on Land) and then scrolls through a slideshow sequence of maps (here, the indicators that constitute SDG 15). Users can activate additional information about a specific indicator based on their interest. Because the atlas is interactive, users also can search for specific indicators or places as well as pan, zoom, retrieve details, and possibly perform additional operators.

Digital atlases can take a number of alternative forms, such as a series of unique web pages hyperlinked from a table of contents or a set of map layers toggled onto the same central basemap. Digital atlases typically include interactivity, particularly the overlay, search, and sequence operators in addition to the more common pan, zoom, and retrieve operators (see Section 4.4). Digital atlases also can serve as the spatial catalogue to a rich array of multimedia about mapped topics, including text, photographs, animations, and videos.

The order of the atlas pages shapes the overall atlas narrative (see Section 4.7). A paper atlas has a fixed narrative, although users often browse pages out of this order. A digital atlas provides more opportunity for breaking from a pre-defined narrative path based on audience backgrounds and interests (see Section 4.1).

An atlas of the SDGs is increasingly possible as more SDGs indicators attain Tier I status (see Section 1.6). The World Bank published an initial compendium on the SDGs using their world development indicators as proxies to the indicators. Creation of an atlas of the SDG indicators has many challenges, such as global distribution, multilingual translation, and regular updates. However, it could be a centerpiece for supporting local and national decision-making as well as public education and advocacy.

4.12 Usability & User-Centred Design

Usability describes the ease of using a product, map or otherwise. The usability of a map is critical to the overall ***user experience***, or the process that leads to a successful and satisfying outcome. It is important to consider usability when making maps and diagrams that portray SDG indicators given the diverse worldwide audiences they may reach (see Section 4.1). What is usable for one audience may not be usable for another.

In practice, usability captures a number of holistic cartographic design considerations relevant to static and digital maps. For instance, several usability measures address the speed of uptake: ***learnability*** describes how easy it is to use the map for the first time while ***memorability*** describes how quickly users can regain proficiency after an extended period without use. ***Efficiency*** describes how quickly users can complete desired tasks with the map after learning how to use it. In contrast to speed-based measures, ***error frequency*** and ***error recovery*** describe how many mistakes users make with a map and how easily they correct these mistakes, respectively. Finally, ***subjective satisfaction*** describes how much users like the map.

In practice, usability is treated together with ***utility***, or the usefulness of the product for its intended purpose. For digital maps, utility can be described as the ***functional requirements*** of application, broken down by datasets (see Section 1.2), representation techniques (i.e., maps or diagrams; see Sections 3.1 and 3.10), and interaction operators (see Section 4.4). ***Non-functional requirements*** then include usability and accessibility (see Section 4.2).

In practice, usability and utility often compete with one another on medium-to-large sized mapping projects: general audience maps privilege transparent usability over inclusion of numerous features while specialist audience maps privilege complex functionality over an easy-to-use interface. To reconcile these competing forces, it is recommended to extend the cartographic workflow introduced in Section 2.2 to follow a more robust ***user-centred design*** process that seeks feedback early and often from the intended audience (Figure 4.12-2).

User-centred design typically begins with a needs assessment study to define intended user personas and use case scenarios (see Section 4.1). The needs assessment then informs the initial ***conceptual design*** identification of functional requirements for the map (i.e., its utility relative to user backgrounds and needs). ***Prototyping*** then translates the functional requirements to rough proofs-of-concepts that propose alternative visual designs that follow the identified non-functional requirements (i.e., usability relative to utility). The conceptual design and prototypes are returned to intended users for feedback, and these users continue to participate in subsequent evaluation and implementation loops as functionality is added to the map. The user-centred design process typically concludes with a ***transition*** stage to transfer and debug the final map release. As with all cartographic design, a user-centred process is highly iterative.

Figure 4.12-1: Functional and non-functional requirements. This book outlines a range of functional and non-functional requirements that define the scope and expectations of any mapping project. Defining and iteratively refining functional and non-functional requirements as part of conceptual design and prototyping streamline a user-centred design process, often saving project time and resources on medium-to-large sized mapping projects.

Functional Requirements

[ ] Data:
- **Location:** Absolute versus relative (see Section 1.3), scale (see Section 2.6), generalization (see Section 2.7), dimensionality (see Section 1.8).
- **Attributes:** Level of measurement (see Section 1.4), transformations and normalization (see Section 1.7), classification (see Section 1.9), missing data (see Section 2.15).
- **Time:** Absolute versus relative, linear versus cyclical (see Section 1.5).

[ ] Representation:
- **Maps:** Symbolization (see Section 2.9), colour (see Section 2.10), typography and toponymy (see Sections 2.11 and 2.12), thematic map types (see Section 3.1).
- **Diagrams:** Univariate (see Section 3.11), comparative (see Section 3.12), multivariate (see Section 3.10), temporal (see Section 3.14).

[ ] Interaction:
- **Interface Styles:** Direct manipulation, menu selection, form fill-in (see Section 4.3).
- **Interaction Operators:** Design, perspective, content (see Section 4.4).

Non- Functional Requirements

[ ] Usability: Learnability, memorability, efficiency, error frequency, error recovery, subjective satisfaction (see Section 4.12).

[ ] Accessibility: Vision impairment, disability, digital divide (see Section 4.2), open access (see Section 4.13).

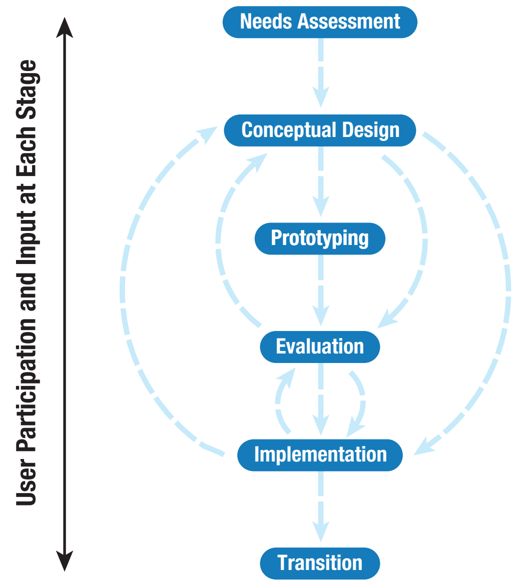


Figure 4.12-2: User-centred design. For medium-to-large sized mapping projects, it often is necessary to extend the cartographic worflow introduced in Section 2.2 to include feedback early and often from the intended audience. A user-centred cartographic design process often includes needs assessment, conceptual design, prototyping, evaluation, implementation, and transition. As with all cartographic design, a user-centred process is highly iterative.

4.13 Open Access

Open access refers to products that are freely available for anyone to use or modify. Open access products can include scholarly or popular writing, datasets such as those on the SDG indicators, maps and diagrams made from open access datasets, and software code. For digital maps, open access relates to the ***Free and Open Source Software*** (FOSS) movement underpinning open web standards (e.g., HTML, CSS, JavaScript) and popular web mapping libraries (e.g., D3.js, Leafelt.js, OpenLayers.js) (see Section 4.5). The aim of open access is to democratize data collection and distribution, improve access to digital technologies, promote knowledge production and sharing, and encourage transparent governance to strengthen accountability, all ultimately to address persistent inequities within society.

The concept of "free" regarding open access has multiple meanings: gratis and libre. Free as in ***gratis*** means free of cost. Open access products have the greatest global uptake when they are made available at no cost, packaged in a convenient and interoperable format, and distributed online for download or streaming. Both the SDG indicator datasets and this book are free of cost to download. Free-of-cost products have the trade-off of limited support and maintenance, increasing the importance of using interoperable standards and collaborative online forums and wikis to reduce the barrier to their use.

Free as in ***libre*** means free to use, modify, and redistribute. The most liberal form of open access allows sharing a product and having no commercial restrictions or other discriminatory practices on subsequent products made from the original. However, open access products often are subject to a ***Creative Commons*** (CC) license that requires Attribution (BY), Share-Alike (SA), Non-Commercial (NC), or No Derivative works (ND). For instance, OpenStreetMap data uses the CC BY-SA version of the license, allowing unrestricted use and extension as long as attribution is given. SDG indicator datasets are unlicensed, containing no conditions for use or modification. Finally, this textbook uses the CC BY-NC version of the license (**Figure 4.13-1**), allowing broader circulation and republishing of text or figures with attribution but restricting commercial applications without first obtaining copyright from the United Nations and International Cartographic Association.

Open access is a major step towards achieving the SDGs by being able to monitor progress and build collective understanding. Because the SDG datasets and the cartographic guidance in this book are openly available, more people than ever before can make maps in support of an economically, environmentally, and socially sustainable future.

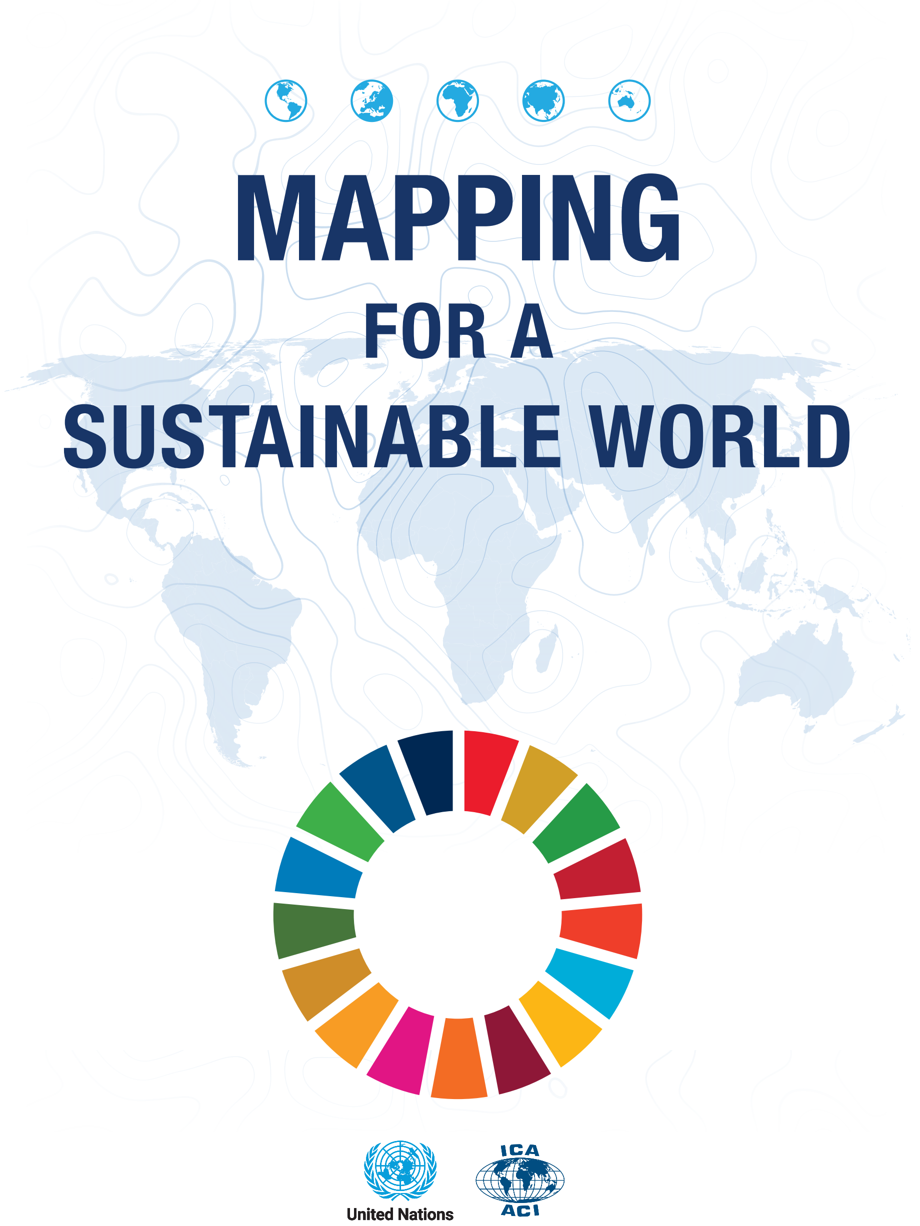


Figure 4.13-1: Mapping for a Sustainable World. This book is available gratis and libre under a CC BY-NC license. When reusing text or figures, attribute as:

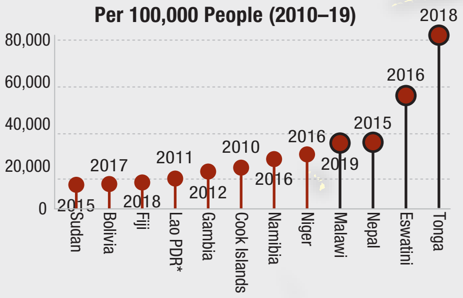
Kraak MJ, RE Roth, B Ricker, A Kagawa, and G Le Sourd. 2020. Mapping for a Sustainable World. The United Nations: New York, NY (USA).

GOAL 13: TAKE URGENT ACTION TO COMBAT CLIMATE CHANGE

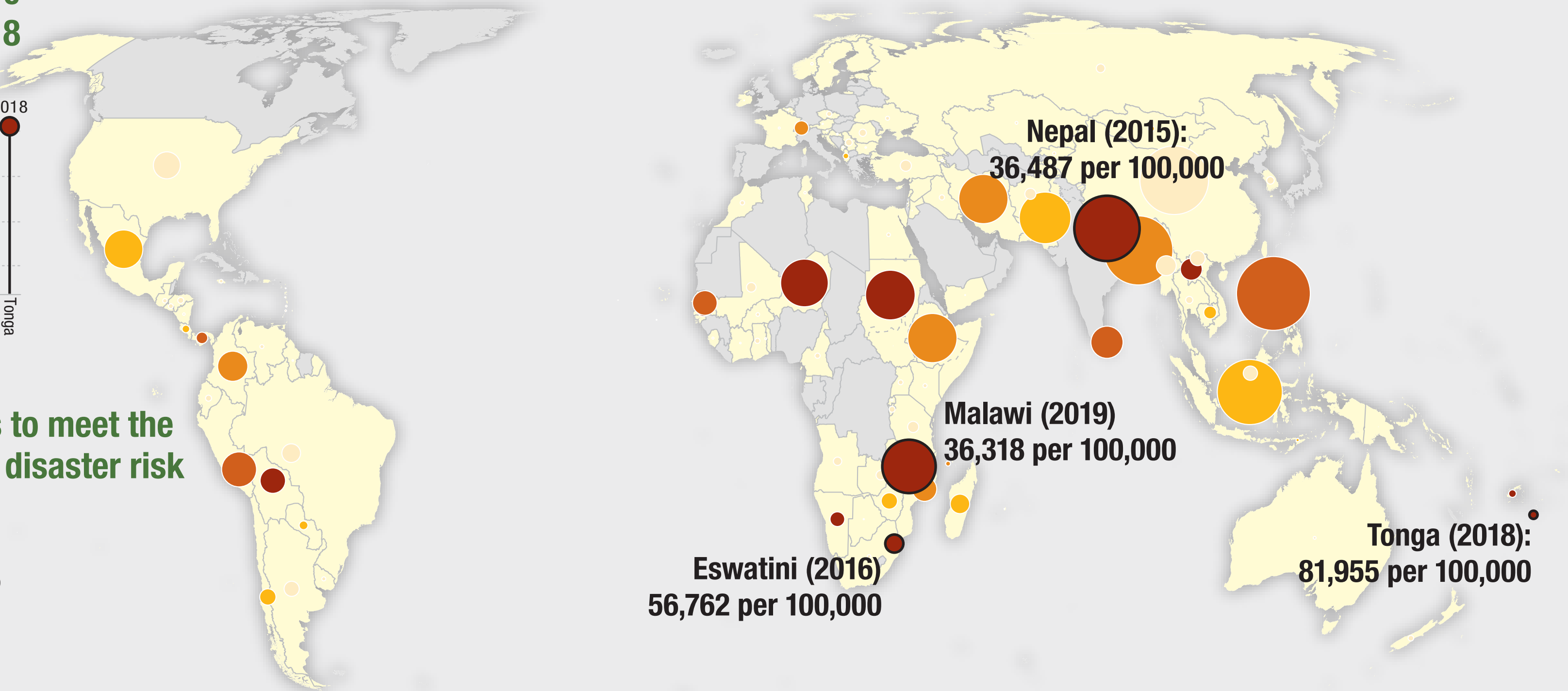
SDG Target 13.1

Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters

► Climate change affected more than 39 million people in 2018



► Only 85 countries have plans to meet the Sendai framework to reduce disaster risk



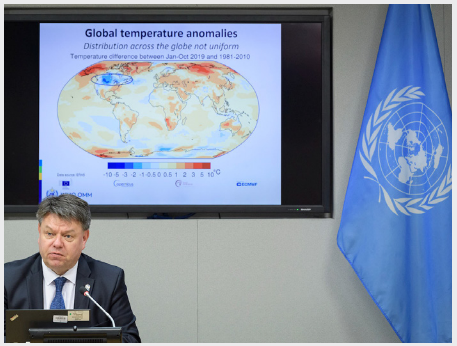
Persons Directly Affected by Disasters (Highest Value 2010–2019)

Total Number

- 5,000,000
- 1,000,000
- 250,000
- Missing data

Per 100,000 People

- 15,000–89,955
- 10,000–15,000
- 5,000–10,000
- 2,500–5,000
- 0–2,500



◄ Secretary-General of the World Meteorological Organization (WMO) briefs reporters on its State of the Climate 2019 Report. A world map of global temperature differences between 1981–2010 and 2019 is shown in the background. (Source: UN Photo/Manuel Elias, 2020)

▲ The map depicts Indicator 13.1.1 (highest value 2010–2019) on directly affected persons attributed to disasters using shaded proportional symbols by country. Affected persons is depicted in two ways: the absolute total as proportional symbols (size) and the relative rate per 100,000 people through shading (colour value).

Climate change affects everyone, but developing countries and marginalized populations often shoulder a disproportionate burden from climate-related hazards such as severe weather, fires and flooding, and food and water scarcity. Representing Indicator 13.1.1 in two ways tells the story of both the overall magnitude of the problem through the proportional symbols and the impact on specific populations through the colour shading.

13 CLIMATE ACTION

Afterword

In the introduction to the book, we asserted that well-designed maps and diagrams can assist governments and people to better understand the Sustainable Development Goals and monitor progress towards alleviating them. Maps make visible social, economic, and environmental processes, revealing spatial patterns that might otherwise go unnoticed through thoughtful projection, generalization, symbolization, typography, visual hierarchy, and so on. In this way, maps scale up the capacity of the human mind to the complexity of our world, even if imperfectly so.

In today's context, maps no longer are static windows into the world. Maps can be interactive or animated and delivered online or through mobile devices. Maps are dynamic and collaborative interfaces that support decision-making by local and national authorities as well as promote public awareness of global issues to encourage these authorities to act. Maps can reach more diverse audiences than ever, customizing their displays to improve accessibility, promote cross-cultural sensitivity, and empower marginalized voices. Maps and cartographers must be part of the solution for addressing the SDGs and achieving a sustainable world.

However, maps both historically and currently are part of the problem, contributing to the global inequities the SDGs seek to dissolve and thus reinforcing dominant power structures. Questions on who can make and access maps—as well as the knowledge to make and access these maps—persist. In this book, we attempt to open this knowledge on cartographic design too often paywalled behind expensive textbooks or university courses. While opening this knowledge is one step towards democratizing cartography, it is not enough to confront the SDGs. We call on the global community of cartographers to continue developing and sharing open data, maps, and mapping technologies to better the world.

To this end, this book summarizes guidelines for mapping geographic datasets related to the SDGs by introducing basic principles of map design and use, discussing established best practices and conventions, and explaining how different mapping techniques support understanding of the SDGs. Importantly, the same subject can be mapped or charted in a number of different, equally appropriate ways, but some design decisions are suboptimal for particular mapping contexts. We emphasize common pitfalls resulting in flawed or even misleading maps and diagrams, but our goal is not to suggest these guidelines as hard-and-fast rules required in all mapping contexts. Instead, our objective is to encourage mapmakers of all kinds to be more intentional about these cartographic design decisions. Reasons to break from our recommendations are myriad, but they should be made with careful and collective consideration of the map use and user context.

Our own journey while preparing this book led to three major observations about mapping the SDGs. First, the open data that is available through the Global SDG Indicators Database often is incomplete. Even within Tier I indicators, data values are missing for a number of countries or reported inconsistently by year. Further, datasets reported by SDG regional grouping or individual country mask spatial patterns within these enumeration units, calling for greater focus on sub-national data compilation, monitoring and reporting as called for in the 2030 agenda. Also, many indicators reinforce problematic binary categories, such as male/female, calling into question who and what are missing from these datasets. While this book focuses on the resulting maps, it is the underlying data that continues to limit global awareness, discourse, and action on our world's most pressing problems.

Second, the story too often told about the SDG indicators is one that more data, and by proxy more maps, will solve the world's problems. Through our experience creating the book, the stories supported by the SDG indicators instead are those of global inequalities, rising interdependencies, and future alternatives. At their best, SDG maps confront our biases and prejudices, helping us to think beyond our personal experiences and consider multiple cultural, ethnic, geographic, political, religious, and sociodemographic contexts. Thus, mapping the SDGs is much more of an ongoing process than a final product. Mapping the SDGs is one of the many ways to share our insights and perspectives—to help us talk to one another as global citizens—and such conversation has no end date or finish line.

Finally, we have come to view the SDGs as an extensible framework for collectively making progress toward a sustainable world. The 18 months spent crafting the book spanned: global social movements to affirm LGBTQIA+ and women's rights, devastating losses to and renewed organization for Indigenous land tenure claims, the Black Lives Matter movement and associated worldwide protests against racism and white supremacy, the Arctic sea ice hitting historic lows and global temperatures reaching worst-case-scenario highs, unprecedented fires from Australia to California and devastating storm flooding from the Caribbean to East Asia, the desert locust invasion threatening food supplies over the Horn of Africa, international youth movements against environmental injustices and for climate action, multilateralism in crisis as exemplified by Brexit and the surge in nationalist political ideologies, and the coronavirus global health emergency and needless death toll exacerbated by unequal access to health care.

The drivers of these issues are not new, but many are only tangentially legible in the SDG indicators. As we progress on the indicators through data and mapping initiatives, we also must remain vigilant to fold-in persistent and emerging challenges facing our world not yet covered by the 2030 Agenda for Sustainable Development. And, as these global challenges evolve and expand, so too will cartographic design best practices and conventions.

We encourage you to join our mapping for a sustainable world.

—MJK, RER, BR, AK, and GLS

Figure Notes

Figure 1.1-1: See https://unsdg.un.org/resources/guidelines-use-sdg-logo-including-colour-wheel-and-17-icons.

Figure 1.2-1: Based on Peuquet, D. J., 1984, "A conceptual framework and comparison of spatial data models," *Cartographica*, vol. 2, no. 4, pp. 66-113.

Figure 1.2-2 (Left): Source OpenStreetMap attribution OpenStreetMap CC BY-SA.

Figure 1.2-3 (Left): Source Joseph Colton, Smithsonian Magazine, **(Right)** Source Google Maps copyright 2020 Google LLC.

Figures 1.3-1 and **Figure 1.3-2:** See https://unstats.un.org/unsd/methodology/m49/.

Figure 1.3-3: See https://unstats.un.org/sdgs/indicators/regional-groups.

Figure 1.5-2: Based on Andrienko, N., Andrienko, G., and Gatalsky, pp., 2003, "Exploratory spatio-temporal visualization: An analytical review," *Journal of Visual Languages and Computing*, vol. 14, pp. 503–541.

Figure 1.6-1: Based on Kraak, M. J., Ricker, B., and Engelhardt, Y., 2018, "Challenges of mapping Sustainable Development Goals indicators data," *ISPRS International Journal of Geo-Information*, vol. 7, no. 12, pp. 482.

Figure 2.6-2: Source OpenStreetMap attribution OpenStreetMap CC BY-SA.

Figure 2.7-2: Based on Roth, R. E., Brewer, C. A., and Stryker, M. S., 2011, "A typology of operators for maintaining legible map designs at multiple scales," *Cartographic Perspectives*, no. 61, pp. 29–64.

Figure 2.9-1: Based on Bertin, J., 1967, *Sémiologie Graphique*, Den Haag, Mouton, as expanded in MacEachren, A.M., 1995, *How Maps Work*, New York, The Guilford Press.

Figure 2.10-1: Based on Roth, R. E., Woodruff, A. W., and Johnson, Z. F., 2010, "Value-by-alpha maps: An alternative technique to the cartogram," *The Cartographic Journal*, vol. 47, no. 2., pp. 130–140.

Figure 2.10-1: Based on Brewer, C. A., 1994, "Colour use guidelines for mapping and visualization," in *Visualization in Modern Computing*, MacEachren, A. M., and Taylor, D. R. F. (Eds), Tarrytown, Elsevier Science.

Figures 2.10-2, **2.10-3**, and **2-10-4:** Based on Brewer, C. A., 2003, "A transition in improving maps: The ColorBrewer example," *Cartography and Geographic Information Systems*, vol. 30, no. 2, pp. 159–162, and ColorBrewer2.org.

Figures 2.11-1 and **2.11-2:** Based on Imhof, E., 1975, "Positioning names on maps," *The American Cartographer*, vol. 2, no. 2, pp. 128–144.

Figure 2.14-1 (Left): Source OpenStreetMap CC BY-SA, **(Left-centre)** Esri World Light Gray Canvas attribution Esri, HERE, Garmin, INCREMENT P, OpenStreetMap CC BY-SA, and GIS user community, **(Right-centre)** CARTO Dark Matter attribution CARTO, OpenStreetMap CC BY-SA, **(Right)** Stamen Watercolor attribution Stamen CC BY 3.0, OpenStreetMap CC BY-SA.

Figure 2.15-2: Based on Kinkeldey, C., MacEachren, A. M., and Schiewe, J., 2014, "How to assess visual communication of uncertainty? A systematic review of geospatial uncertainty visualization user studies," *The Cartographic Journal*, vol. 51, no. 4, pp. 372–386.

Figure 3.1-1: Based on MacEachren, A. M., and DiBiase, D., 1991, "Animated maps of aggregate data: Conceptual and practical problems," *Cartography and Geographic Information Systems*, vol. 18, no. 4, pp. 221–229.

Figure 3.7-1: Based on Nelson, E. S., 2000, "Designing effective bivariate symbols: The influence of perceptual grouping processes," *Cartography and Geographic Information Systems*, vol. 27, no. 4, pp. 261–278.

Figure 4.1-1: Based on MacEachren, A. M., and Kraak, M. J., 1997, "Exploratory cartographic visualization: Advancing the agenda," *Computers & Geosciences*, vol. 23, no. 4, pp. 335–343.

Figure 4.1-2: See D'Ignazio, C., and Klein, L., 2020, *Data Feminism*, Boston, MIT Press for comprehensive discussion on individual differences and intersectional identities.

Figures 4.2-1 and **4.2-2:** Based on Brewer, C. A., 2003, "A transition in improving maps: The ColorBrewer example," *Cartography and Geographic Information Systems*, vol. 30, no. 2, pp. 159–162, and ColorBrewer2.org.

Figure 4.3-1: Based on Norman, D. A., 1988, *The Design of Everyday Things*, New York, Basic Books and Shneiderman, B., and Plaisant, C., 2010, *Designing the User Interface: Strategies for Effective Human-Computer Interaction*, Boston, Addison-Wesley.

Figure 4.4-1: Based on Roth, R. E., "An empirically-derived taxonomy of interaction primitives for Interactive Cartography and Geovisualization," *IEEE Transactions in Visualization and Computer Graphics*, vol. 19, no. 12, pp. 2356–2365.

Figure 4.5-1: See: https://geoservices.un.org/webapps/geohub/.

Figure 4.5-2: Icons from Wikimedia Commons unless otherwise noted. Icons for online mapping platforms copyright Esri, CARTO, and Mapbox.

Figures 4.6-1 and **4.6-2:** Based on Ricker, B., and Roth, R. E., 2018, "Mobile maps and responsive design," in *The Geographic Information Science & Technology Body of Knowledge*, Wilson, J. pp. (Ed), University Consortium for Geographic Information Science.

Figure 4.8-1: Based on Kraak, M. J., 2014, *Mapping Time*, Redlands, Esri Press.

Figures 4.9-1 and **4.9-2:** Based on Few, S., 2006, *Information Dashboard Design: The Effective Visual Communication of Data*, Sebastopol, O'Reilly.

Figures 4.10-1, **4.10-2**, and **4.10-3:** Based on Shneiderman, B., 1996, "The eyes have it: A task by data type taxonomy for information visualization" in *Proceedings of the IEEE Symposium on Visual Languages*, Boulder, IEEE.

Figure 4.12-1: Based on Robinson, A. C., Chen, J., Lengerich, E. J., Meyer, H. G., and MacEachren, A. M., 2005, "Combining usability techniques to design geovisualization tools for epidemiology," *Cartography and Geographic Information Systems*, vol. 32, no. 4, pp. 243–255.

Glossary

The following glossary presents terms as they are defined and used in this book:

2030 Agenda for Sustainable Development: see **Sustainable Development Goals (SDGs)** (Section 1.1, pp. 2–3)

Absolute attribute: see **Attribute** (Section 1.4, pp. 8–9)

Absolute location: see **Location** (Section 1.3, pp. 6–7)

Absolute time: see **Time** (Section 1.5, pp. 10–11)

Accessibility: the ability to obtain and benefit from a map, with the goal of supporting the widest possible range of audiences (Section 4.2, pp. 92–93)

Accuracy: the correctness of the data (Section 2.15, pp. 52–53); see also **Uncertainty**

Adjacent maps: the representation of multiple attributes, data with its uncertainty, or a time series on separate maps (Section 2.15, pp. 52–53;); also called **Small multiples**

Aggregate: an increase in dimensionality (Section 2.8, pp. 38–39); see also **Generalization operator**

Analysis: the confirmation of hypotheses generated during exploration (Section 4.10, pp. 108–109); see also **Cartography Cube**

Analytical dashboard: see **Dashboard** (Section 4.9, pp. 106–107)

Animation: the use of digital system time to update the map display (Section 4.8, pp. 104–105)
- ***temporal animation:*** an animation with display time representing real-world time
- ***non-temporal animation:*** an animation with frames ordered to facilitate understanding of the map

Arithmetic classification scheme: see **Classification scheme** (Section 1.9, pp. 18-19)

Arrange: an interactive change to the layout of maps and diagrams (Section 4.4, pp. 96–97); see also **Interaction operator**

Arrangement: the layout of graphic marks in the symbol (Section 2.9, pp. 40–41); see also **Visual variable**

Aspect: orientation of the map surface to the globe (Section 2.5, pp. 32–33)
- ***normal aspect:*** orientation of the map surface to the Earth's axis of rotation, resulting in standard parallels
- ***transverse aspect:*** orientation of the map surface 90° from the axis of rotation, resulting in standard meridians
- ***oblique aspect:*** all aspects that are not normal or transverse

Aspect ratio: horizontal versus vertical dimensions of the layout (e.g., portrait versus landscape) (Section 2.13, pp. 48–49)

Atlas: an intentional sequence of maps, text, and other graphic elements depicting different dimensions of geographic phenomena and processes (Section 4.11, pp. 110–111)

Attribute: the *what* or *who* of data (Section 1.4, pp. 8–9); see also **Geospatial data**
- ***absolute attribute:*** an attribute measured or counted and reported without consideration of other attributes

- ***enumerated attribute:*** an individual-level attribute that is aggregated or counted within a predefined space, or enumeration unit
- ***individual-level attribute:*** unique conditions or qualities of a specific place
- ***relative attribute:*** an attribute that is normalized based on one, two, or multiple other values

Attribute change: see **Change** (Section 1.5, pp. 10–11)

Audience: the intended users of the map (Section 2.1, pp. 24–25; Section 4.1, pp. 90–91)

Azimuthal projection: see **Projection** (Section 2.4, pp. 30–31)

Bar chart: a univariate diagram using rectangular bars to depict the distribution of an attribute across different nominal categories (Section 3.11, pp. 78–79)

Binary map: a thematic map showing two categories such as presence/absence or yes/no (Section 3.2, pp. 60–61)

Bivariate map: a thematic map depicting two data attributes (Section 3.7, pp. 70–71)
- ***configural bivariate map:*** a bivariate map that maintains reading of the original X and Y attributes while including a visual hint about the + relationship that can be used for visual correlation
- ***integral bivariate map:*** a bivariate map that restricts reading of the original X and Y indicators but promotes reading of the + relationship between indicators
- ***separable bivariate map:*** bivariate map that preserves reading of both original X and Y indicators in the map

Bubble chart: a variant of a scatterplot that depicts a third attribute by resizing the point symbol (Section 3.13, pp. 82–83)

Calculate: an interactive derivation of new information from the map (Section 4.4, pp. 96–97); see also **Interaction operator**

Cartogram: a thematic map that scales the area of each enumeration unit by its attribute value (Section 3.8, pp. 72–73)
- ***contiguous cartogram:*** a cartogram that maintains topology between enumeration units while compromising on shape
- ***non-contiguous cartogram:*** a cartogram that maintains shape completely by scaling each enumeration unit within its boundary

Cartography: the art, science, and technology of making and using maps (Introduction, pp. v)

Cartography Cube: a framework that organizes broad map use cases according to three axes: map users, map use tasks, and map interactivity (Section 4.1, pp. 90–91)

Cartographic scale: the ratio between a distance represented on a map and the corresponding distance in the real world (Section 2.6, pp. 34–35)
- ***large cartographic scale:*** a representative fraction that computes to a relatively larger decimal number, resulting in a map depicting small geographic scale phenomenon
- ***small cartographic scale:*** a representative fraction that computes to a small decimal number, resulting in a map depicting large geographic scale phenomenon

Cascading Style Sheets (CSS): an open web standard used to style contents of a web document (Section 4.5, pp. 98–99)

Glossary

Central meridian: the longitude along which the map surface of a projection is focused (Section 2.5, pp. 32–33); see also **Projection**

Change: a difference over time (Section 1.5, pp. 10–11)
- ***attribute change:*** qualitative (e.g., same or different) or quantitative (e.g., increase or decrease) change over time
- ***existential change:*** appearance and disappearance over time
- ***location change:*** movement, expansion, or shrinking over time

Change blindness: a visual phenomenon in which the audience misses a large amount of the information in an animation due to the increased visual complexity (Section 4.8, pp. 104–105)

Change Map: a representation of time that calculates the difference between two data captures in the time series (Section 3.9, pp. 74–75)

Chart: see **Diagram** (Section 3.10, pp. 76–77)

Choropleth map: a thematic map that shades enumeration units by their attribute values, primarily relying on colour value (Section 3.3, pp. 68–69)

Class break: a division point between classes within a classification scheme (Section 1.9, pp. 18–19)

Classification: the process of organizing map features into groups to improve legibility in the representation (Section 1.9, pp. 18–19)

Classification scheme: the set of class breaks and their logic for organizing map features into groups (Section 1.9, pp. 18–19)
- ***arithmetic classification scheme:*** a classification scheme with an increase or decrease in distances between class breaks in a regular progression
- ***equal interval classification scheme:*** a classification scheme that places class breaks equidistant from each other
- ***geometric classification scheme:*** a variant of the arithmetic classification scheme in which distances between class breaks increase or decrease geometrically (e.g., doubling, tripling, etc.)
- ***mean & standard deviation classification scheme:*** a variant of the equal interval classification scheme in which the equal interval is in standard deviations from the mean
- ***optimal breaks classification scheme:*** treatment of classes like clusters by minimizing differences within each class and maximizing differences among classes
- ***quantile classification scheme:*** placement of the same number of features into each class

Client-side technologies: web technologies used to render data, such as maps and diagrams, in the browser for viewing and manipulation by the user (Section 4.5, pp. 98–99)

CMYK: a subtractive colour model (*C*yan, *M*agenta, *Y*ellow, and blac*K*) used for designing print maps and diagrams that reflect light (Section 2.10, pp. 42–43)

Coincident map: the representation of multiple attributes, data with its uncertainty, or a time series in a single map (Section 2.15, pp. 52–53)

Collapse: a decrease in dimensionality (Section 2.8, pp. 38–39); see also **Generalization operator**

Colour: the electromagnetic spectrum perceived by the eye (Section 2.10, pp. 42–43); see also **Visual style**

Colour hue: the dominant wavelength of the symbol colour (Section 2.10, pp. 42–43); see also **Visual variable**

Colour saturation: the spectral purity of the symbol colour (Section 2.10, pp. 42–43); see also **Visual variable**

Colour scheme: the set of colour symbols and their logic for representing attributes in maps and diagrams (Section 1.9, pp. 18–19)
- ***diverging colour scheme:*** a colour scheme combining two sequential schemes to create an apparent increase in two directions
- ***qualitative colour scheme:*** a colour scheme with no apparent order
- ***sequential colour scheme:*** a colour scheme with an apparent increase from low-to-high
- ***spectral colour scheme:*** a rainbow scheme of red, orange, yellow, green, cyan, blue, indigo, violet

Colour value: the spectral strength of the symbol colour (Section 2.10, pp. 42–43); see also **Visual variable**

Column chart: a bar chart that is vertically oriented (Section 3.11, pp. 78–79); see also **Bar chart**

Compilation: a visual storytelling genre that enforces continuity through the order of unfolding events (newer first) (Section 4.7, pp. 102–103); see also **Visual storytelling genre**

Completeness: the amount of missing data values (Section 2.15, pp. 52–53); see also **Trustworthiness**, **Uncertainty**

Compromise projection: see **Projection** (Section 2.4, pp. 30–31)

Conceptual design: see **Design** (Section 4.12, pp. 112–113); see also **User-centred design**

Configural bivariate map: see **Bivariate map** (Section 3.7, pp. 70–71)

Configure controls: the controls in interactive maps that set-up interaction for the map user before use of the map (Section 4.3, pp. 94–95)

Conflict: the middle of the three-act narrative containing the key problem motivating the story (Section 4.73, pp. 102–103); see also **Three-act narrative**

Conformal projection: see **Projection** (Section 2.4, pp. 30–31)

Conic projection: see **Projection** (Section 2.4, pp. 30–31)

Consistency: the uniformity in data collection (Section 2.15, pp. 52–53); see also **Trustworthiness**, **Uncertainty**

Context controls: the controls in interactive maps that allow adding contextual information after initial use of the map (Section 4.3, pp. 94–95)

Contiguous cartogram: see **Cartogram** (Section 3.8, pp. 72–73)

Coordination: interaction across multiple maps and diagrams, with an interaction operator applied in one view also applied to all others (Section 4.10, pp. 108–109)

Creative Commons (CC): an open access license that may carry Attribution (BY), Share-Alike (SA), Non-Commercial (NC), or No Derivative works (ND) restrictions for use of the product (Section 4.13, pp. 114–115)

Credibility: the reliability of the data source (Section 2.15, pp. 52–53); see also **Trustworthiness**, **Uncertainty**

Crispness: the sharpness of symbol edges (Section 2.9, pp. 40–41); see also **Visual variable**

Currency: the age of the data (Section 2.15, pp. 52–53); see also **Trustworthiness**, **Uncertainty**

Cyclical time: see **Time** (Section 1.5, pp. 10–11)

Cylindrical projection: see **Projection** (Section 2.4, pp. 30–31)

Data transformation: statistical conversion of an attribute (Section 1.7, pp. 14–15); see also **Level of measurement**, **Normalization**

Dashboard: a visual summary of data, often displayed as multiple maps and diagrams of different locations, attributes, or time periods on a single screen (Section 4.9, pp. 106–107)

- ***analytical dashboard:*** a dashboard with extensive information and interactive functionality for generating and evaluating previously unknown insights into patterns, trends, and anomalies across a range of datasets
- ***operational dashboard:*** a dashboard with relatively simple maps and diagrams depicting real-time data streams and alerts when thresholds are surpassed, requiring urgent response
- ***strategic dashboard:*** a dashboard providing an overview of key data parameters that policy and decision-makers need to measure and monitor

Dasymetric map: a thematic map that leverages ancillary geospatial data to redraw borders of enumeration units, often at a finer spatial resolution, that better reflect the spatial distribution of the mapped phenomenon (Section 3.5, pp. 66–67)

Design: **1.** the process of planning, executing, and evaluating a map; **2.** individual decisions that a cartographer must make to represent the selected geospatial datasets visually; **3.** the final product of the cartographic design process (Section 2.3, pp. 28–29)

- ***conceptual design:*** identification of the functional requirements of a map as informed by a needs assessment
- ***inclusive design:*** design for the most marginalized users first, rather than an imagined “average” or “normal” audience
- ***mobile-first design:*** design that is optimized for the technological constraints of mobile devices, which include small screen displays, reduced processing power and memory capacity, unreliable connectivity and reduced bandwidth, limited battery life, and multitouch interaction
- ***responsive design:*** the design logic for changing the layout, content, and styling of digital maps between mobile and non-mobile devices
- ***user-centred design:*** a design process that seeks feedback early and often from the intended audience

Diagram: a representation of non-geographic attribute and temporal data patterns (Section 3.10, pp. 76–77); also called a **Chart** or **Graph**

Digital divide: the divide between those that have access to the internet and its underlying computer technology and those that do not (Section 4.5, pp. 98–99)

Dimensionality: the minimum number of coordinates needed to specify an object’s location (Section 2.8, pp. 38–39)

Direct manipulation: a visual interface style supporting probing, dragging, or adjusting of graphics through clicking (for non-mobile) or tapping (for mobile) (Section 4.3, pp. 94–95)

Displace: an adjustment to the location of a feature to avoid coalescence with adjacent features (Section 2.7, pp. 36–37); see also **Generalization operator**

Glossary

Diverging colour scheme: see **Colour scheme** (Section 2.10, pp. 42–43)

Donut chart: a modified pie chart that removes the centre, emphasizing the relative size of the donut slice over the shape of the subdivisions (Section 3.12, pp. 80–81)

Dot density map: a thematic map using the composite visual variable numerousness to adjust the density of dots placed within enumeration units by their attribute values (Section 3.1, pp. 58–59)

Dot map: a nominal map in which each dot on the map corresponds to a single place (Section 3.2, pp. 60–61)

Dumbbell chart: a comparative or temporal diagram depicting a pair of sub-categories or time stamps as a single-size interval (3.12, pp. 80–81)

Dynamic slideshows: a visual storytelling genre that enforces continuity through the order of slides (Section 4.7, pp. 102–103); see also **Visual storytelling genre**

Ecological fallacy: the same individual-level data enumerated at different boundary resolutions (i.e., geographic scales) results in different statistical relationships in the enumerated attributes (Section 1.8, pp. 16–17)

Efficiency: the speed a user can complete desired tasks with the map after learning how to use it (Section 4.12, pp. 112–113); see also **Usability**

Endonym: a toponym originating from within the named place (Section 2.12, pp. 46–47)

Enhance: the addition of symbol embellishments around or within existing symbols to maintain or clarify relationships among symbols (Section 2.7, pp. 36–37); see also **Generalization operator**

Entry point: the first click or tap upon entering an interactive map (Section 4.3, pp. 94–95)

Enumerated attribute: see **Attribute** (Section 1.4, pp. 8–9)

Enumeration unit: a pre-defined space within which an individual-level attribute is aggregated or counted (Section 1.4, pp. 8–9)

Environment: the medium on and setting in which the map is used (Section 2.1, pp. 24–25)

Equal interval classification scheme: see **Classification scheme** (Section 1.9, pp. 18–19)

Equal-area projection: see **Projection** (Section 2.4, pp. 30–31)

Equalizing variable: an attribute that statistically or visually normalizes the variable of interest (Section 3.8, pp. 72–73)

Equator: the zero reference for north-south notations of latitude (Section 2.5, pp. 32–33)

Equidistant projection: see **Projection** (Section 2.4, pp. 30–31)

Equivalent projection: see **Projection** (Section 2.4, pp. 30–31)

Error frequency: the amount of mistakes users make with a map (Section 4.12, pp. 112–113); see also **Usability**

Glossary

Error recovery: the ease that users correct mistakes (Section 4.12, pp. 112–113); see also **Usability**

Exaggerate: an amplification of a portion of the map feature to emphasize a characteristic aspect of it when changing cartographic scale (Section 2.7, pp. 36–37); see also **Generalization operator**

Exclusionary geospatial data: see **Geospatial data** (Section 3.5, pp. 66–67)

Existential change: see **Change** (Section 1.5, pp. 10–11)

Exonym: a toponym originating from outside of the named place (Section 2.12, pp. 46–47)

Exploration: specialized use of interactive maps and diagrams to generate previously unknown insights into geographic phenomena and processes (Section 4.10, pp. 108–109); see also **Cartography Cube**

Extrinsic map: the representation of multiple attributes, data with its uncertainty, or a time series as separate data layers (Section 2.15, pp. 52–53)

Figure: the map features that rise to the foreground in the visual hierarchy (Section 2.13, pp. 48–49)

Filter: an interactive reduction of depicted map features by given criteria (Section 4.4, pp. 96–97); see also **Interaction operator**

Flow map: a thematic map of linear features that symbolizes attribute relationships between places rather than attribute values at places (Section 3.2, pp. 60–61)

Fly-through: an animation that changes the viewpoint perspective to the map (Section 4.8, pp. 104–105)

Form: the variable aspects of the geospatial linework, including its generalized detail and line weights, caps and joint styles, and tapering (Section 2.14, pp. 50–51); see also **Visual style**

Form fill-in: a visual interface style supporting the keying of characters to indicate parameters of the interaction (Section 4.3, pp. 94–95)

Frame: a single visual instance within an animation sequence (Section 4.8, pp. 104–105)

Free and Open Source Software (FOSS): the movement underpinning open web standards and popular web mapping libraries to democratize data collection and distribution, improve access to digital technologies, promote knowledge production and sharing, and encourage transparent governance to strengthen accountability, all ultimately to address persistent inequities within society (Section 4.13, pp. 114–115)

Functional requirements: the planned map features broken down by datasets, representation techniques, and interaction operators (Section 4.12, pp. 112–113)

General users: the public at large (Section 4.1, pp. 90–91); see also **Cartography Cube**

Generalization: the process of meaningfully removing detail from the map to support the map's purpose, audience, and use environment (Section 2.7, pp. 36–37)

Generalization operator: a generic modification to map design made to reduce complexity and maintain legibility when changing cartographic scale (Section 2.7, pp. 36–37)

Geographic coordinates: absolute (X,Y) locations based on the Earth's geometry and measured in degrees latitude and longitude (Section 1.2, pp. 4–5)

Geographic scale: the size and extent of a geographic phenomenon (Section 1.8, pp. 16–17)
- ***large geographic scale:*** national-level geographic phenomenon in coarser detail
- ***small geographic scale:*** local-level geographic phenomenon in finer detail

Geometric classification scheme: see **Classification scheme** (Section 1.9, pp. 18–19)

Geospatial data: data describing aspects of the natural and built environments with the components of location, attribute(s), and time (Section 1.2, pp. 4–5)
- ***exclusionary geographic data:*** data that defines locations where the mapped phenomenon cannot exist
- ***inclusionary geographic data:*** data that defines locations where the mapped phenomenon can exist, often in different amounts

Geovisual analytics: the use of visual interfaces to computational processes in support of exploration and analysis (Section 4.10, pp. 108–109)

Global indicator framework: a framework for reporting the SDGs at global, regional, national, and local levels comprising 17 goals, 169 targets, and 231 indicators as of April 2020 (Section 1.1, pp. 2–3)

Global Positioning System (GPS): the geospatialv navigational system using satellite signals to capture location information in three-dimensions on the Earth's surface (Section 4.6, pp. 100–101)

Goal: one of the 17 most pressing challenges facing a sustainable world (Section 1.1, pp. 2–3); see also **Global indicator framework**

Graduated symbol map: a proportional symbol map that has been classified or range-graded (Section 3.4, pp. 64–65); see also **Range grading**

Graph: see **Diagram** (Section 3.10, pp. 76–77)

Graphic association: a clear connection between map feature and label (Section 2.11, pp. 44–45)

Graticule: a network of latitude and longitude intervals that can be projected in the map as an indication of north (Section 1.2, pp. 4–5); see also **Geographic Coordinates**

Gratis: open access products that are free of cost (Section 4.13, pp. 114–115)

Grid: a network of regular columns and/or rows to organize layout (Section 4.11, pp. 110–111)

Ground: the map features that recede to the background in the visual hierarchy (Section 2.13, pp. 48-49)

Gutter: a gap in the layout (Section 4.11, pp. 110–111)

Histogram: a univariate diagram that bins numerical data into mutually exclusive and exhaustive classes (Section 3.11, pp. 78–79)

Hypertext Markup Language (HTML): an open web standard used to structure the content of a web document (Section 4.5, pp. 98–99)

Icon: a map symbol that resembles prominent visual characteristics associated with the mapped category (Section 3.4, pp. 64–65)

Inclusionary geospatial data: see **Geospatial data** (Section 3.5, pp. 66–67)

Inclusive design: see **Design** (Section 4.2, pp. 92–93)

Glossary

Index: a relative attribute created from multiple values belonging to multiple attributes using a formula (Section 1.4, pp. 8–9)

Indicator: geospatial datasets used to measure and monitor progress towards each target, to inform policy, and to ensure accountability of all stakeholders, 231 in total as of April 2020 (Section 1.1, pp. 2–3); see also **Global indicator framework**

Individual-level attribute: see **Attribute** (Section 1.4, pp. 8–9)

Integral bivariate map: see **Bivariate map** (Section 3.7, pp. 70–71)

Inter-Agency and Expert Group on SDG Indicators (IAEG-SDGs): the group facilitated by the United Nations that is responsible for uniting the global community to develop and implement the global indicator framework (Section 1.1, pp. 2–3)

Interaction: a conversation or series of question-and-answer sequences between the user and map mediated by digital computing technology (Section 4.3, pp. 94–95)

Interactive maps: maps that enable interaction (Section 4.3, pp. 94–95)

Interaction operator: generic interactive functionality that enables users to manipulate the map display (Section 4.4, pp. 96–97)

Interface: a digital tool used to manipulate onscreen elements (Section 4.3, pp. 94–95)

Internet: a series of interconnected computer networks that facilitate the transfer of files (Section 4.5, pp. 98–99)

Interrelatedness: the dependence of the data on the quality of other datasets (Section 2.15, pp. 52–53); see also **Trustworthiness**, **Uncertainty**

Interruption: a slice in the projection to reduce local distortions in each resulting map lobe (Section 2.5, pp. 32–33); see also **Projection**

Interval-level data: see **Level of measurement** (Section 1.4, pp. 8–9)

Intrinsic map: the representation of multiple attributes, data with its uncertainty, or a time series as a single data layer by modifying the applied symbolization (Section 2.15, pp. 52–53)

Integral bivariate map: see **Bivariate map** (Section 3.7, pp. 70–71)

Interruption: a slice in the projection to reduce local distortions in each resulting map lobe (Section 2.5, pp. 32–33); see also **Projection**

Isoline map: a thematic map that interpolates between sampled attribute values, using the visual variable location to represent the interpolated attribute gradient as a new geospatial data layer (Section 3.1, pp. 58–59)

JavaScript: a scripting language used to add interactive behaviours to elements in a web document (Section 4.5, pp. 98–99)

JavaScript Object Notation (JSON): an open web file format with GeoJSON and TopoJSON as geospatial variants (Section 4.5, pp. 98–99)

Key: see **Legend** (Section 3.6, pp. 68–69)

Glossary

Label: map text (Section 2.11, pp. 44–45)

Large cartographic scale: see **Cartographic scale** (Section 2.6, pp. 34–35)

Large geographic scale: see **Geographic scale** (Section 1.8, pp. 16–17)

Latitude: parallels measured north and south of the equator (Section 1.2, pp. 4–5); see also **Geographic Coordinates**

Layout: the placement of map elements on the map page or screen (Section 2.13, pp. 48–49)

Learnability: the speed with which a map is used for the first time (Section 4.12, pp. 112–113); see also **Usability**

Legend: a description of each kind of symbol included in the map (Section 3.6, pp. 68–69); also called a **Key**

Levels of measurement: the data scales on which attributes are collected or transformed (Section 1.4, pp. 8–9)
- ***interval-level data:*** attribute data that is quantitative, but the zero value is arbitrary and, thus, limits estimation of relative magnitudes
- ***nominal-level data:*** attribute data that is unranked categories
- ***ordinal-level data:*** attribute data that is non-numerical and ranked
- ***ratio-level data:*** attribute data that is quantitative values with a fixed zero

Libre: open access products free to use, modify, and redistribute (Section 4.13, pp. 114–115)

Line chart: a temporal diagram that weaves a line trace through multiple time stamps or periods of a single attribute (Section 3.14, pp. 90–91)

Line: an unenclosed set of nodes and arcs in a vector data model (Section 1.3, pp. 6–7)

Lineage: the data transformation process (Section 2.15, pp. 52–53); see also **Trustworthiness**, **Uncertainty**

Linear time: see **Time** (Section 1.5, pp. 10–11)

Location: **1.** the *where* of geospatial data (Section 1.3, pp. 6–7); **2.** the symbol position in the layout (Section 2.9, pp. 40–41); see also **Geospatial data**, **Visual variable**
- ***absolute location:*** spatial coordinates in a pre-defined reference system
- ***relative location:*** directions from an arbitrary landmark or other location

Location-based services: web services that customize maps and information to the user's current location (Section 4.6, pp. 100–101)

Location change: see **Change** (Section 1.5, pp. 10–11)

Lollipop chart: a variant of the bar chart or histogram that uses a more minimal line anchored with a point symbol at the data value, taking up less overall space in the layout (Section 3.11, pp. 78–79)

Longform infographics: a visual storytelling genre that enforces continuity through vertical reading and browser scrolling (Section 4.7, pp. 102–103); see also **Visual storytelling Genre**

Longitude: meridians measured east and west of the prime meridian (Section 1.2, pp. 4–5); see also **Geographic Coordinates**

M49 code: a three-digit numerical coding system for polygonal geographic regions used for statistical processing by the Statistics Division of the United Nations (Section 1.3, pp. 6–7)

M49 country: a sovereign political administrative unit acknowledged in the M49 standard (Section 1.3, pp. 6–7); see also **M49 standard**

M49 intermediate region: a division of a sub-region in the M49 standard for statistical purposes (Section 1.3, pp. 6–7); see also **M49 standard**

M49 region: a major continental region in the M49 standard (Section 1.3, pp. 6–7); see also **M49 standard**

M49 standard: a multi-level, global set of region, sub-region, and intermediate region groupings identified by the M49 codes (Section 1.3, pp. 6–7); also called the **Standard Country or Area Codes for Statistical Use**

M49 sub-regions: a division of a continental region in the M49 standard for statistical purposes (Section 1.3, pp. 6–7); see also **M49 standard**

Map: an abstracted and authored (often) visual representation of geographic phenomena or processes (Section 2.3, pp. 28–29)

Map element: an item placed in the map layout such as the title, legend, indication of scale and north, the map itself, and other text and annotation (Section 2.13, pp. 48–49)

Marimekko chart: a variant of a stacked bar chart that normalizes bar widths to compare both relative percentages and absolute totals (Section 3.12, pp. 80–81)

Mathematical scaling: proportional symbol scaling directly relating the area of the symbol to the attribute value (Section 3.4, pp. 64–65)

Mean: the sum of all values divided by total observations (Section 3.2, pp. 60–61)

Mean & standard deviation classification scheme: see also **Classification scheme** (Section 1.9, pp. 18–19)

Median: the middle observation when ordered (Section 3.2, pp. 60–61)

Memorability: the speed users can regain proficiency with the map after an extended period without use (Section 4.12, pp. 112–113); see also **Usability**

Menu selection: a visual interface style supporting selection of one or more options from a visual list (Section 4.3, pp. 94–95)

Merge: a combination of multiple features into one feature while maintaining dimensionality (Section 2.8, pp. 38–39); see also **Generalization operator**

Missing data: the absence of an attribute value for a particular location and year (Section 2.15, pp. 52–53)

Mobile device: a mobile or handheld portable computing systems such as a smartphone, smartwatch, or tablet (Section 4.6, pp. 100–101)

Mobile map: A map accessed on a mobile device (Section 4.6, pp. 100–101)

Mobile-first design: see **Design** (Section 4.6, pp. 100–101)

Glossary

Mode: the most common value found within the polygonal enumeration unit (Section 3.2, pp. 60–61)

Modifiable areal unit problem (MAUP): a mapping issue in which the same individual-level data when enumerated to different sets of polygonal boundaries results in different visual patterns in the map (Section 1.8, pp. 16–17)

Multimedia visual experiences: a visual storytelling genre that enforces continuity through anchor tags and hyperlinks (Section 4.7, pp. 102–103); see also **Visual storytelling genre**

Multivariate: a map or diagram depicting three or more attributes (Section 3.13, pp. 82–83)

Narrated animations: a visual storytelling genre that enforces continuity through the progression of display time (Section 4.7, pp. 102–103); see also **Visual storytelling genre**

Narrative: the structure and presentation of story content shaping its meaning (Section 4.7, pp. 102–103)
- ***three-act narrative:*** a narrative arc presented in three parts including the set-up, conflict, and resolution

Needs assessment: a study at the beginning of user-centred design to define intended user personas and use case scenarios (Section 4.12, pp. 90–91); see also **User-centred design**

Negative space: unused layout space created by the shape of the mapped area and gaps between other map elements (Section 2.13, pp. 48–49)

Nominal-level data: see **Level of measurement** (Section 1.4, pp. 8-9); also called **Qualitative data**

Nominal map: a thematic map that depicts categorical data and thus relies on unordered visual variables (Section 3.2, pp. 60–61)

Non-contiguous cartogram: see **Cartogram** (Section 3.8, p 72–73)

Non-functional requirements: considerations for maps other than datasets, representation techniques, and interaction operators, which includes usability and accessibility (Section 4.12, pp. 112–113)

Non-temporal animation: see **Animation** (Section 4.8, pp. 104–105)

Normal aspect: see **Aspect** (Section 2.5, pp. 32–33)

Normalization: the conversion of absolute attributes to relative attributes to mask privacy of individual-level data and to ensure visual comparability of enumerated
data across enumeration units of varying arrangement, shape, and size (Section 1.4, pp. 8–9); see also **Data transformation**

Numerical data: interval- and ratio-level data together (Section 1.4, pp. 8–9); also called **Quantitative data**

Numerousness: A composite visual variable including arrangement and size (Section 3.1, pp. 58–59)

Oblique aspect: see **Aspect** (Section 2.5, pp. 32–33)

Open access: products that are freely available for anyone to use or modify (Section 4.13, pp. 114–115)

Operational dashboard: see **Dashboard** (Section 4.9, pp. 106–107)

Optimal breaks classification scheme: see also **Classification scheme** (Section 1.9, pp. 18–19)

Ordered visual variable: see **Visual variable** (Section 2.9, pp. 40–41)

Ordinal-level data: see **Level of measurement** (Section 1.4, pp. 8–9)

Orientation: the rotation of the symbol (Section 2.9, pp. 40–41); see also **Visual variable**

Overlay: an interactive addition or removal of data layers atop the basemap or underlay of different basemaps (Section 4.4, pp. 96–97); see also **Interaction operator**

Overprinting: the overlap of labels on features or labels on labels (Section 2.11, pp. 44–45)

Pan: an interactive change to the projection centring (Section 4.4, pp. 96–97); see also **Interaction operator**

Parallel coordinate plot: a multivariate diagram extending the spatial metaphor of a scatterplot to align three or more coordinate frames in a linear rather than orthogonal (right angle) layout (Section 3.13, pp. 82–83)

Perceptual scaling: proportional symbol scaling that accounts for systematic underestimation of 2D and 3D dimensions as symbols grow larger (Section 3.4, pp. 64–65)

Personalized story maps: a visual storytelling genre that enforces continuity through the order of user contributions (older first) (Section 4.7, pp. 102–103); see also **Visual storytelling genre**

Pictorial unit chart: a variant of the unit chart that modifies the regular grid of the unit chart by stacking iconic point symbols (Section 3.11, pp. 78–79)

Pie chart: a comparative diagram showing relative proportions as slices in a circular pie (Section 3.12, pp. 80–81)

Planar projections: see **Projection** (Section 2.4, pp. 30–31)

Point: a single node in a vector data model (Section 1.3, pp. 6–7)

Polygon: an enclosed set of nodes and arcs in a vector data model (Section 1.3, pp. 6–7)

Precision: the exactness of the data (Section 2.15, pp. 52–53); see also **Uncertainty**

Presentation: the effective and efficient visual communication from cartographer to a wider audience following cartographic design recommendations, resulting in a single map (Section 4.10, pp. 108-109); see also **Cartography Cube**

Prime meridian: the zero reference at Greenwich, England, for east-west notations of longitude (Section 2.5, pp. 32–33)

Project Plan: the series of steps from conceptualization to final delivery during cartographic design (Section 2.2, pp. 26–27)

Projection: the process of transferring geospatial data from a three-dimensional model of the Earth to a two-dimensional or "flat" map (Section 2.4, pp. 30–31)

- ***azimuthal projection:*** a projection that preserves directions from a single point to all other points on the map
- ***compromise projection:*** a projection that balances distortion across all map properties
- ***conformal projection:*** a projection that preserves angular relationships at infinitely small points, often heavily distorting areas as a result
- ***conic projection:*** a projection that conceptually wraps the map surface around one hemisphere of the globe, resulting in a semi-circular graticule
- ***cylindrical projection:*** a projection that conceptually wraps the map surface completely around the globe, with the unfurled surface resulting in a rectangular graticule
- ***equal-area / equivalent projection:*** a projection that preserves the relative areas of polygon features, often heavily distorting shape as a result
- ***equidistant projection:*** a projection that preserves distance from either one point (planar) or two points (cylindrical and conic) to all other points on the map
- ***planar projection:*** a projection that conceptually places the map surface on the globe, resulting in a circular graticule
- ***secant projection:*** a projection that slices the globe with the map surface, producing two standard lines for conic and cylindrical projections and one standard line for planar projections
- ***tangent projection:*** a projection that touches the map surface to the globe, producing one standard line for conic and cylindrical projections and one standard point for planar projections

Proportion: a relative attribute created from two values belonging to the same attribute (Section 1.4, pp. 8–9)

Proportional symbol map: a thematic map that uses the visual variable size to scale point symbols by their attribute values (Section 3.4, pp. 64–65)

Prototyping: the translation of functional requirements to rough proofs-of-concepts that propose alternative visual designs (Section 4.12, pp. 112–113); see also **User-centred design**

Purpose: the overall goal in producing the map (Section 2.1, pp. 24–25)

Qualitative data: see **Nominal-level data** (Section 1.4, pp. 8–9)

Qualitative colour scheme: see **Colour scheme** (Section 2.10, pp. 42–43)

Quantile classification scheme: see **Classification scheme** (Section 1.9, pp. 18–19)

Quantitative data: see **Numerical data** (Section 1.4, pp. 8–9)

Quantitative visual variable: see **Visual variable** (Section 2.9, pp. 40–41)

Radar chart: a multivariate diagram that arranges three or more coordinates circularly rather than linearly in the parallel coordinate plot, with a common base or zero coordinate (Section 3.13, pp. 82–83); also called a **Star plot**

Rainbow colour scheme: see **Spectral colour scheme** (Section 2.10, pp. 42–43)

Range grading: the classification of proportional symbols, with the resulting map described as a graduated symbol map (Section 3.4, pp. 64–65); see **Graduated symbol map**

Rate: a relative attribute created from two values belonging to two different attributes (Section 1.4, pp. 8–9)

Ratio-level data: see **Level of measurement** (Section 1.4, pp. 8–9)

Reexpress: an interactive change to a different thematic map type or diagram using the same data (Section 4.4, pp. 96–97); see also **Interaction operator**

Relative attribute: see **Attribute** (Section 1.4, pp. 8–9)

Relative location: see **Location** (Section 1.3, pp. 6–7)

Relative time: see **Time** (Section 1.5, pp. 10–11)

Representation: a thing (e.g., a map or diagram) that stands for another thing (e.g., real-world geographic phenomena and processes) (Section 2.3, pp. 28–29)

Representative fraction: a numerical indication of cartographic scale comprising the fraction between measurements in the map and the real-world (Section 2.6, pp. 34–35)

Reproject: an interactive change to the map projection distortions (Section 4.4, pp. 96–97); see also **Interaction operator**

Resolution: **1.** the level of detail of the symbol (Section 2.9, pp. 40–41); **2.** the end of the three-act narrative containing the climatic issue facing the characters and one or several solutions for the narrative (Section 4.7, pp. 102–103); see also **Three-act narrative**, **Visual variable**

Responsive design: see **Design** (Section 4.6, pp. 100–101)

Resymbolize: **1.** the visual styling of selected map features when changing cartographic scale (Section 2.7, pp. 36–37); **2.** an interactive change to the design parameters of the map, such as the classification or colour scheme (Section 4.4, pp. 96–97); see also **Generalization operator**, **Interaction operator**

Retrieve: an interactive acquisition of additional details on-demand for specific map features of interest (Section 4.4, pp. 96–97); see also **Interaction operator**

RGB: an additive colour model (*R*ed, *G*reen, and *B*lue) used for designing digital maps and diagrams that emit light (Section 2.10, pp. 42–43)

Sans serif typeface: a typeface without serif embellishments that evoke the clean lines of the build environment handwriting (Section 2.11, pp. 44–45)

Scalable Vector Graphics (SVG): an open image format for drawing vector data (Section 4.5, pp. 98–99)

Scale: see **Cartographic scale** (Section 2.6, pp. 34–35), **Geographic scale** (Section 1.8, pp. 16–17)

Scale bar: a graphic indication of cartographic scale using a line to show a benchmark distance (Section 2.6, pp. 34–35)

Scatterplot: a bivariate diagram depicting data elements as point coordinates in a two-dimensional statistical space (Section 3.13, pp. 82–83)

Screen real estate: the proportion of the onscreen layout dedicated to the map, interface controls, etc. (Section 4.3, pp. 94–95)

Search: an interactive identification of specific map features of interest (Section 4.4, pp. 96–97); see also **Interaction operator**

Secant projection: see **Projection** (Section 2.5, pp. 32–33)

Selection: the retention or removal of map features (Section 2.1, pp. 24–25); see also **Generalization operator**

Glossary

Separable bivariate map: see **Bivariate map** (Section 3.7, pp. 70–71)

Sequence: an interactive progression through an ordered set of maps, as with an animation (Section 4.4, pp. 96–97); see also **Interaction operator**

Sequential colour scheme: see **Colour scheme** (Section 2.10, pp. 42–43)

Serif typeface: a typeface with serif embellishments that mimic handwriting and the uneven edges of the natural environment (Section 2.11, pp. 44–45)

Server-side technologies: web technologies used to store data, including geospatial datasets (Section 4.5, pp. 98–99)

Set-up: the beginning of the three-act narrative containing background context such as the setting and key characters (Section 4.73, pp. 102–103); see also **Three-act narrative**

Shape: the external form of the symbol (Section 2.9, pp. 40–41); see also **Visual variable**

Simplify: a reduction to the number of nodes that constitute a feature (Section 2.7, pp. 36–37); see also **Generalization operator**

Simultaneous contrast: a visual phenomenon in which the appearance of one colour in the map may shift based on surrounding colours (Section 2.10, pp. 42–43)

Size: the amount of space occupied by the symbol (Section 2.9, pp. 40–41); see also **Visual variable**

Slippy web map: see **Web map** (Section 4.5, pp. 98–99)

Slope chart: a comparative or temporal diagram that modifies the dumbbell chart to include an emergent orientation visual cue, suggesting an increase or decrease instead of a difference (Section 3.12, pp. 80–81)

Small cartographic scale: see **Cartographic scale** (Section 2.6, pp. 34–35)

Small geographic scale: see **Geographic scale** (Section 1.8, pp. 16–17)

Small multiples: see **Adjacent maps** (Section 3.9, pp. 74–75)

Smooth: a removal of small, jagged variations in the nodes and arcs (Section 2.7, pp. 36–37); see also **Generalization operator**

Sorted stream graph: see **Stream graph** (Section 3.14, pp. 90–91)

Spatial autocorrelation: near locations are more likely to be similar in attribute and time than distant locations (Section 1.3, pp. 6–7)

Specialist users: cartographers, statisticians, and other stakeholders with motivation, expertise, and interest relevant to the mapping context (Section 4.1, pp. 90–91); see also **Cartography Cube**

Spectral colour scheme: see **Colour scheme** (Section 2.10, pp. 42–43); also called a **Rainbow colour scheme**

Spread: a two-page layout for folded printing (Section 4.11, pp. 110–111)

Stacked area chart: a variant of the line chart that adds quantities on top of one another to combine towards the overall total (Section 3.14, pp. 90-91)

Stacked bar chart: a comparative variant of the bar chart that divides a bar chart to show relative contributions to the total from sub-categories (Section 3.12, pp. 80–81)

Standard Country or Area Codes for Statistical Use: see **M49 standard** (Section 1.3, pp. 6–7)

Standard Line: a line in a projection where the map surface and globe conceptually touch or intersect and, therefore, a line on the project map where geographic scale is accurate (Section 2.4, pp. 30–31)

Standard Point: a point in the projection where the map surface and globe conceptually touch, only found on tangent planar projections (Section 2.4, pp. 30–31)

Star plot: see **Radar chart** (Section 3.13, pp. 82–83)

Static visual stories: a visual storytelling genre that enforces continuity through layout partitioning and annotation (Section 4.7, pp. 102–103); see also **Visual storytelling genre**

Story: information about specific events, places, and people combined into a narrative (Section 4.7, pp. 102–103)

Story map: a cartographic representation that exhibits narrative elements (Section 4.7, pp. 102–103)

Storytelling: a method of documenting or explaining a sequence of events (Section 4.7, pp. 102–103)
- ***visual storytelling:*** a story communicated through maps, graphics, images, and videos along with other forms of oral, written, and audio storytelling

Strategic dashboard: see **Dashboard** (Section 4.9, pp. 106–107)

Stream graph: a temporal diagram that resizes a "stream" or conceptual line symbol, with thickness of the line symbol encoding the data value at a given time stamp or interval (Section 3.14, pp. 90–91)
- ***sorted stream graph:*** a variant of the stream graph that reorders line symbols vertically across the diagram so that the largest value always is at the top of the diagram

Subject: the *who*, *what*, *when*, and *where*, or the spatiotemporal context, for the map (Section 2.1, pp. 24–25)

Subjective satisfaction: the degree users like the map (Section 4.12, pp. 112–113)

Subjectivity: the degree of human interpretation during the data transformation process (Section 2.15, pp. 52–53); see also **Trustworthiness**, **Uncertainty**

Sustainable Development Goals (SDGs): the overarching blueprint to achieve a better and more sustainable future for all and to address global challenges, adopted in 2015 by the Member States of the United Nations (Section 1.1, pp. 2–3); also called the **2030 Agenda for Sustainable Development**

Symbolization: the graphic encoding of data in a map or diagram (Section 2.9, pp. 40–41)

Synthesis: the combination of evidence and findings from exploration and analysis to support subsequent presentation for visual communication (Section 4.10, pp. 108–109); see also **Cartography Cube**

Tangent projection: see **Projection** (Section 2.5, pp. 32-33)

Glossary

Target: the real and actionable outcomes for reaching the SDGs, 169 in total as of April 2020 (Section 1.1, pp. 2–3); see also **Global indicator framework**

Temporal animation: see **Animation** (Section 4.8, pp.104–105)

Temporal scale: the ratio between a display time and real-world time (Section 4.8, pp. 104–105)

Texture: the coarseness of graphic marks in the symbol (Section 2.9, pp. 40–41); see also **Visual style**, **Visual variable**

Thematic map: a map that depicts the variation of one or sometimes several geographic phenomena (Section 3.1, pp. 58–59)

Three-act narrative: see **Narrative** (Section 4.7, pp. 102–103)

Tier: a classification of indicator data by the IAEG-SDGs based on methodological consistency in collection and global data availability (Section 1.6, pp. 12–13)

Tier I: the indicator is conceptually clear, has an internationally established methodology, and standards are available; data are regularly produced by countries for at least 50 per cent of countries and 50 per cent of the population in every region where the indicator is relevant (Section 1.6, pp. 12–13)

Tier II: the indicator is conceptually clear, has an internationally established methodology, and standards are available, but data are not regularly produced by countries (Section 1.6, pp. 12–13)

Tier Pending: the indicator is awaiting a data availability review (Section 1.6, pp. 12–13)

Time: the *when* an event occurred at the specified location or *when* the data was collected (Section 1.5, pp. 10–11); see also **Geospatial data**
- ***absolute time:*** time measured by calendars and clocks
- ***cyclical time:*** sequences of events that repeat in perpetuity
- ***linear time:*** events proceeding in a regular succession without repetition
- ***relative time:*** an event or period described in comparison to others

Time series: geospatial data on the same attribute collected recurrently over a regular time stamp or time interval (Section 1.5, pp. 10–11)

Toponym: a geographic place name (Section 2.12, pp. 46–47)

Toponymy: the study of place names, their origins, meanings, and uses (Section 2.12, pp. 46–47)

Transition: the transfer and debugging of the final map release with target audiences in the intended map use environment (Section 4.12, pp. 112–113); see also **User-centred design**

Transliteration: the conversion of toponyms to alternative languages and alphabets for global identification (Section 2.12, pp. 46–47)

Transparency: the graphic blending among symbol (Section 2.9, pp. 40–41); see also **Visual variable**

Transverse aspect: see **Aspect** (Section 2.5, pp. 32–33)

Trustworthiness: the confidence in the data (Section 2.15, pp. 52–53); also see **Uncertainty**

Typography: the styling and placement of text (Section 2.11, pp. 44–45); see also **Visual style**

Uncertainty: the gap between the reality represented in the map and the understanding the audience derives from the map (Section 2.15, pp. 52–53)

Unit chart: a variant of the bar chart or histogram that adds the design embellishment of a regular grid to enable counting of exact frequencies and easier comparison of distant bars (Section 3.11, pp. 78–79)

United Nations Group of Experts on Geographical Names (UNGEGN): a group that assists national place-name efforts and facilitates discussion of best practices on toponymy (Section 2.12, pp. 46–47)

Univariate: a map or diagram depicting one attribute (Section 3.11, pp. 78–79)

Unordered visual variable: see **Visual variable** (Section 2.9, pp. 40–41)

Usability: the ease of using a product, map or otherwise (Section 4.12, pp. 112–113)

User experience: the process that leads to a successful and satisfying outcome for the map user (Section 4.12, pp. 112–113)

User-centred design: see **Design** (Section 4.12, pp. 112–113)

Utility: the usefulness of the product, map or otherwise, for its intended purpose (Section 4.12, pp. 112–113)

Variable of interest: the attribute that is statistically or visually normalized by the equalizing variable (Section 3.8, pp. 72–73)

Vector data model: a data model describing locations as nodes comprising pairwise (X,Y) coordinates and arcs connecting nodes to form of points, lines, polygons, and volumes (Section 1.3, pp. 6–7)

Verbal statement: a plain language indication of cartographic scale that makes the relationship conceptually easier to understand (Section 2.6, pp. 34–35)

Visual affordances: the visual signals to the user about how to interact with the provided controls (Section 4.3, pp. 94–95)

Visual art: visual creative works that help humans share experiences of the world, promote empathy and compassion about uneven social and environmental conditions,
and inform policy and politics for forging a sustainable future (Section 2.14, pp. 50–51)

Visual culture: visual cultural artefacts that reflect humanity's interests and values, confront its failures and prejudices, and reveal potential alternatives and opportunities (Section 2.14, pp. 50–51)

Visual feedback: the visual signals about what happened as a result of the interaction (Section 4.3, pp. 94–95)

Visual hierarchy: the order that map elements are perceived visually (Section 2.13, pp. 48–49)

Visual impairment: limitations in visual abilities including individuals who are low-sighted and require corrected vision, are colour vision deficient ("colour-blind"), or are non-sighted (i.e., blind) (Section 4.2, pp. 92–93)

Glossary

Visual metaphor: a visual representation that evokes characteristics of the mapped phenomenon not explicitly expressed within the data (Section 3.1, pp. 58–59)

Visual storytelling: see **Storytelling** (Section 4.7, pp. 102–103)

Visual storytelling genre: a category of visual stories, characterized by a specific way of enforcing continuity across a narrative arc (Section 4.7, pp. 102–103)

Visual style: a cohesive set of design characteristics and qualities that reinforce the purpose of the map (Section 2.14, pp. 50–51)

Visual variable: a way that a symbol can be modified to convey information (Section 2.9, pp. 40–41)
- *ordered visual variable:* a visual variable with an apparent ranking, including colour value, colour saturation, transparency, crispness, and resolution
- *quantitative visual variable:* a visual variable with an apparent magnitude, including location and size
- *unordered visual variable:* a visual variable without an apparent ranking, including shape, orientation, arrangement, texture, and colour hue

Volume: an unenclosed, three-dimensional object in a vector data model (Section 1.3, pp. 6–7)

Waffle chart: a comparative diagram that infills a ten-by-ten-square grid, with each cell representing one per cent (Section 3.12, pp. 80–81)

Web: see **World Wide Web** (Section 4.5, pp. 98–99)

Web map: a map shared over the internet and rendered in a web browser (Section 4.5, pp. 98–99)
- *slippy web map:* a tile-based web map that includes panning and zooming

Web stack: a compilation of multiple, specialized web tools and techniques for developing and hosting web maps (Section 4.5, pp. 98–99)

Working Group on Geospatial Information (WG-GI): a subgroup of the IAEG-SDGs that informs how geospatial data can contribute to SDG indicator development and improve national and sub-national reporting (Section 1.1, pp. 2–3)

World Wide Web: the interconnected documents shared over the internet and rendered in a web browser (Section 4.5, pp. 98–99); also called the **Web**

Zero: the absence of a phenomenon within an enumeration unit (Section 2.15, pp. 52–53)

Zone of aggregation: the arrangement and shape of the polygonal boundaries used for enumerating individual-level data (Section 1.8, pp. 16–17); see also **Enumeration unit**

Zoom: an interactive change to the cartographic scale (Section 4.4, pp. 96–97); see also **Interaction operator**

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