# Chapter 7
# Visualising Spaces of Global Inaccessibility

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**Abstract** Wilderness is normally visualised using conventional mapping approaches showing the least touched spaces on the planet. Because most of the world's population lives in very limited spaces, this is a useful method of representation. The effects of human action, however, go much further than that, resulting in much of the land area being relatively close to humankind while the remotest and 'wildest' spaces are very little areas on a normal map. This chapter looks at alternative ways to visualise the most remote parts of the land area: by deploying a so-called gridded cartogram transformation to data about the (in)accessibility of a place, the resulting cartograms reveal the areas and the extent of the remotest spaces in a much less common way. Gridded cartograms are created by using an equally distributed grid onto which a density-equalising cartogram technique is applied. Each individual grid cell is resized according to its the average travel time to the nearest larger city. This technique is not only applied to the global scale, but also to regional and national-level data. The results are maps that give the remotest places most space and provide a unique and highly visual perspective on the spatial dimension of remoteness.

**Keywords** Cartograms • Gridded cartograms • Accessibility • Travel times • Remoteness

## 7.1 Introduction

Wilderness and remote areas are a diverse element in the patchwork of spaces that form the land surface of our planet. Only very small amounts of people are living in sparsely populated areas, which is an expression of the strong organisation of human societies to maximise those living in close relative proximity. More than half of the world's population now lives in areas categorised as cities, and although more than 95 % of the world's population live in approximately only 10 % of the land area, the

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remaining 90 % of the earth's land surface is far from being uniformly remote or even wild.

There are very different ways of how the un-built area that still makes the largest share of the land surface can be understood in terms of being under influence and in reach of human civilization. Only 15 % of people in rich countries live more than an hour of travel time from a city (of at least 50,000 people), while the same applies to 65 % of people living in the poor countries of the world. These are dimensions that conventional map projections hardly convey in their mere focus on generating images of the land surface and its physical extent. This chapter demonstrates a different cartographic approach to visualising and understanding these loneliest places on the planet by using a technique called a gridded cartogram transformation.

In this chapter, the gridded cartogram technique is used to visualise the relative distance of areas to the majority of people as calculated in an analysis of people's closeness (Uchida and Nelson 2010). The maps derived from the distorted grid show the physical space transformed according to the absolute travel time that is needed to reach the nearest major city by land transport averaged over the area of a grid cell. This results in a map that gives the remotest places the most space and provides a unique new and highly visual perspective on the spatial dimension of remoteness.

## 7.2 Data

The usefulness of gridded cartograms, like other cartograms, depends crucially on the data that goes into the cartogram transformation. Gridded cartograms require a different level of detail, but also a good variability within the quantitative data to result in meaningful and valuable visualisations.

A gridded population cartogram (Hennig 2013) is an effective visualisation of human space. It allows highlighting approximately 10 % of the land area where more than 95 % of the world's population live (Uchida and Nelson 2010), while the remaining 90 % of the land area vanishes in the visual display.

The optimal grid data for a gridded cartogram transformation thus needs a high spatial variation and a data distribution that has the highest values for the topic of interest in a limited amount of grid cells. For example, the major population densities cover approximately 10 % of the full grid (which is why a reverse view of the unpopulated areas appears much less striking). If that were not the case it would be less valuable, as it would not result in that unique new shape and could possibly be similarly well mapped with less methodological effort on a conventional map. One advantage of gridded cartograms is that of a suitable way to highlight selected areas that are in the centre of interest, while other spaces are blurred out.

This raises the question whether the least populated areas can be shown and emphasised with a similar approach. Defining wilderness and remoteness as merely unpopulated areas is less valuable for a cartogram visualisation, as most of the land surface of the planet still remains relatively unpopulated. A cartogram highlighting the least populated places (e.g. by reversing population data so that the least populated areas get the highest data values) results in a map that looks very similar to a conventional world map, with only some of the most populated regions being slightly smaller in size. Other concepts are therefore needed to look at the places that are least impacted by humankind.

The issue of less well-distributed data can be tackled if the underlying geographic dimension is more complex than a plain look at the depopulated areas. The interest in understanding less populated areas is also an issue of understanding the difference between the areas least and most touched by humanity, and the differences in their accessibility. Remoteness can therefore not only be a different way of understanding population patterns, but also of finding those areas that are still places of wilderness.

Some places are remoter than others regardless of their mere physical distance from people. One concept of understanding remote places in a more heterogeneous way is that of the accessibility and inaccessibility of places beyond their distance to major agglomerations. Data that analyses the (in)accessibility of places has been developed in a study on travel times to cities from any given point on the land surface by means of land transportation (Nelson 2008; Uchida and Nelson 2010). The data gives a different picture of remote places and helps to understand the accessibility of people and places beyond their relative distance in physical space. The data therefore also contains some information about the extent of natural areas that are less influenced by humankind.

The multifaceted dataset of travel times (Fig. 7.1) combines a number of different data sources from the physical and human environment to estimate the average travel times to the nearest major city defined by the authors of the study as one of the 8518 cities with 50,000 or more people. The data differentiates the concept of remoteness in a more detailed way by differentiating the least populated areas further than only making a statement about the population density. The indicators used

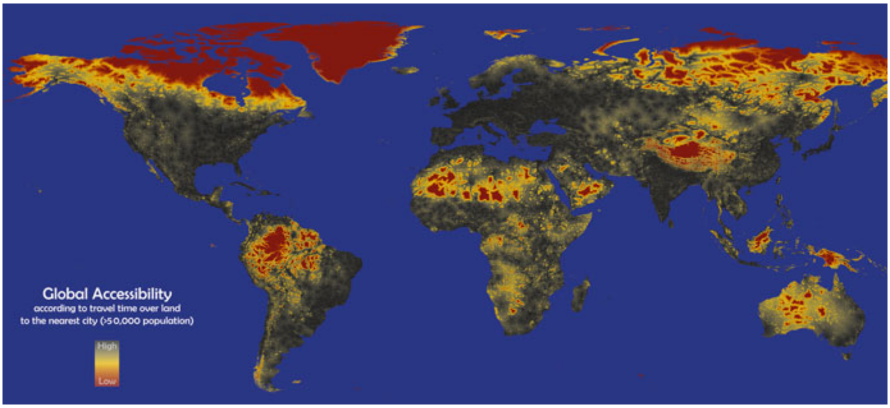


**Fig. 7.1** Global accessibility according to travel time over land to the nearest city over 50,000 population (Own depiction by the author using data by Hengl 2011 and Nelson 2008)

to assess the travel times include all means of transport (rail and road network, rivers), travel times depending on the mode of transport and the kind of transport infrastructure, and the character and structure of the terrain (elevation, slope, land cover) (Nelson 2008; Uchida and Nelson 2010).

For the work presented in this chapter the information about the absolute travel time from a given point was converted into a grid with the least accessible places (and the longest travel time) containing the highest values. The data contained in the grid translates remoteness into a quantifiable measure that combines the human and physical space in one geospatial layer. The gridded dataset is then suitable for a gridded cartogram transformation based on the absolute travel time that is necessary to reach the nearest major city.

## 7.3 Methods

The maps presented in this chapter are based on research using gridded population cartograms as a novel approach to mapping quantitative data. The major improvement of the technique is the much higher precision in the transformed maps that allow cartogram-techniques to be used as an alternative map projection. This does not only result in maps that preserve the topology in the transformed spaces at a very high accuracy, but also in maps that allow other layers of geographic information to be reprojected accordingly (described in detail in Hennig 2013, 2014).

Gridded cartograms adapt a diffusion-based method for producing density equalising maps published by Gastner and Newman (2004). Their work outlines an advanced computer-generation of contiguous cartograms that Dorling (2006: 35) describes as "*one small step for two men, one giant leap for mapping*". These so-called diffusion cartograms transfer the physics of a linear diffusion process into the process of a map transformation.

The diffusion equation used in Gastner/Newman's approach emulates what happens when a liquid flows from higher to lower densities to smooth out the differences. In the map transformation, the diffusion equation smoothes out the differences in densities that are contained in the underlying data which results in distorted shapes of the original geographical areas. Like most cartogram approaches, Gastner/Newman's method is usually applied to countries or other larger administrative units. In a gridded cartogram however, the data is distributed onto an equally-sized grid or raster common to any GIS. This grid is then resized according to these quantities while preserving the relative position of each grid cell towards its neighbouring cells. The key unit in the cartogram transformation thus is not an arbitrarily or artificially defined administrative or other area, but a defined section of a map, with each areal unit having the same geographical extent (see more details described in Hennig 2013, 2014).

> Unlike conventional cartograms, gridded cartograms are capable of displaying additional layers of geographic information in large detail because they are based on a very accurate and neutral areal unit. Any way of putting information on a conventional map can be applied

to gridded cartograms. This can include any geographic subject with an allocation in the physical space (Hennig 2014).

The gridded cartogram approach results in a novel – yet unusual – map projection as the result are maps with a coherent and consistent base that never changes, while most other cartograms are more or less advanced (geo)graphical displays of quantitative data. Gridded cartograms preserve topological relations with a high spatial accuracy and allow other layers of spatial information to be re-projected accordingly.

In the original research on the technique, gridded population cartograms have proven to add further value when scaled to a particular area of interest, enhancing the level of detail and the information that can be derived from it considerably (Hennig 2013; Hennig et al 2010). Data availability defines the limitations of the technique, as the larger scales highly depend on the accuracy of the underlying raster of these maps.

A gridded population cartogram shows the world's geography in relation to the settlement patterns of humanity. This basic concept can be applied to any topic, meaning that it is not limited to socio-economic issues as they are normally chosen for cartogram depictions. On a global scale a gridded population cartogram was generated on the base of a ¼° population grid using data by CIESIN and CIAT (2005). Such a gridded population cartogram provided the basis for a first map transformation of the global accessibility.

The physical environment can be measured much more easily than the extent of the various dimensions of social space. Remote sensing technology and a huge network of measuring equipment constantly monitors a vast amount of data from the physical environment. This provides a solid base of quantitative data from the natural world that is of a very different level of detail than almost any other data that exists for the human world. Global accessibility combines these two worlds in an advanced way and brings data from the social and physical environment together.

Innovative geovisualisations generated from this data are rare, and most visualisations rely on the world map as the main choice for that data. Basic principles of cartographic practice are used to depict quantities. By applying the same principle of a grid that is transformed according to a quantitative indicator, a gridded cartogram transformation of global inaccessibility according to the total travel times to the nearest major cities can be realised.

The transformed grid thus shows each grid cell resized according to that absolute travel time that is needed to reach that area from the nearest major city by land transport. The method results in a map giving the remotest places most space on the map.

## 7.4 Results

Gridded population cartograms show land area distorted to the extent that every human being living on that surface is given the same amount of space on the map. In the resulting map every areal unit for which the total population is counted is transformed accordingly. Consequently the grid cell as the smallest areal unit in a

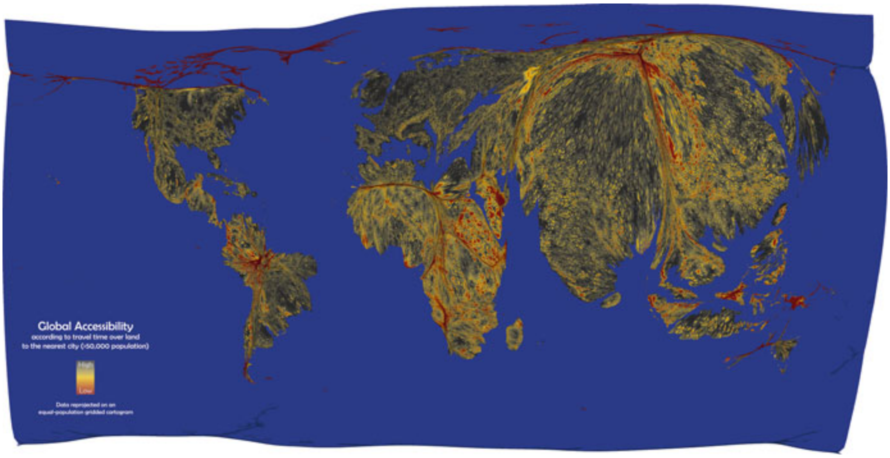


**Fig. 7.2** Global accessibility according to travel time over land to the nearest city over 50,000 population shown on a gridded population cartogram (Own depiction by the author using data by CIESIN and CIAT 2005; Hengl 2011; Nelson 2008)

gridded cartogram is the smallest geographical reference to the physical space. The area that is covered in the original raster is the same area in the resulting gridded cartogram, hence the new maps show the number of people living in the same geographical space.

When transforming additional layers of geographic information alongside a gridded population cartogram, these topics can be interpreted accordingly and thus provide a deeper understanding of the topic in relation to the world population. In areas with few people, this additional layer is reduced in size because it does not relate directly to a larger amount of people. The underlying information is not removed in these areas of low population, but reduced in size and can be made visible by enlarging the area of interest. All original grid cells can be recognised in the gridded cartograms and no information is lost in the transformation process.

New layers of geographical information add further value to the gridded population cartograms. If seen as a new geographic map projection, then any ways of putting information on a conventional map can also work with gridded cartograms.

In the analysis of people's closeness, Nelson (2008) points out that only 15 % of people in rich countries live more than an hour of travel time from a major city, while the same applies to 65 % of people living in the poor countries of the world. The map showing travel time to major cities re-projected on a gridded population cartogram highlights this difference (Fig. 7.2). The colour scheme reflects the travel times to the nearest larger city as used in the conventional version of this map (Fig. 7.1). The value of the new projection becomes apparent, as the equal population projection demonstrates that not all parts of the world's population are equally accessible, and that in some regions large proportions of people live in relatively less accessible places. This is, for example, the case in some parts of Africa and the Arabian Peninsula where people live in relative remoteness to larger agglomerations

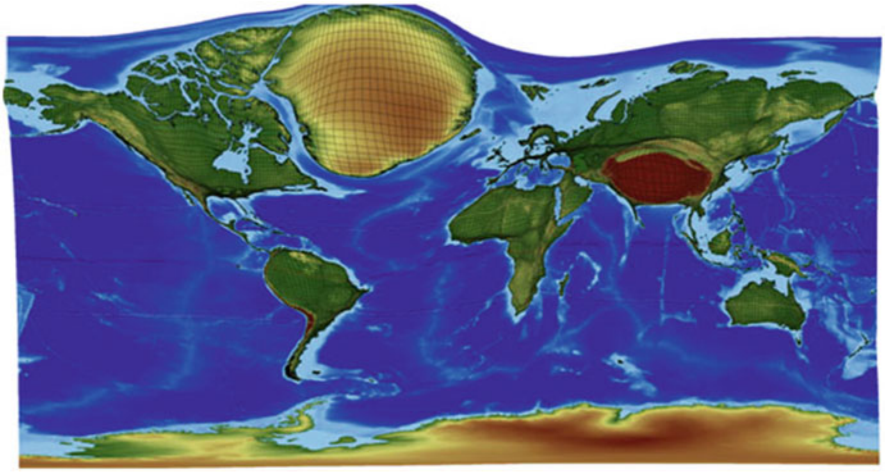

**Fig. 7.3** Gridded cartogram of travel times to the nearest city over 50,000 population (Excluding Antarctica, own depiction by the author using data from CIESIN and CIAT 2005; Hengl 2011; Nelson 2008; NOAA 2009; USGS 2009)

although they are embedded in a denser population pattern, while this relative solitude hardly exists in Europe any more, where the transport infrastructure allows even the remotest parts that people see as distant and *wild to* be accessed much faster.

Population, however, is not the most suitable way of seeing and understanding the distribution of these remote areas. Here a gridded cartogram transformation of these spaces according to their relative inaccessibility creates a much more vivid impression of these last of the wild areas. Due to the nature of gridded cartograms, other geospatial layers can be transformed, so that for example the world's topography can be visualised in its correct geographic relation to the transformed maps. This can support the readability of the sometimes quite abstract shapes in the distorted maps.

The gridded cartogram of the remotest places on a global scale visualises the picture of a lonely planet (Fig. 7.3) where the spaces shown are those that are furthest away from those places of civilisation that define the twenty-first century. More than half of the world's population according to UN estimates now lives in cities (UNPD 2009), and this map shows those places that most of the people living in the world need the longest time to get to. It draws an image of the areas that are almost disconnected from those shrinking effects of globalisation, the real areas of wilderness that still surround us. This world map is the striking opposite representation of our image of a globalised and interconnected world, of those vanishing places that many people think do not exist any more.

The method of gridded cartograms is also scalable and can show remote places of a limited area, such as regions or individual countries. The resulting maps highlight further detail that cannot be seen on a global scale, which can give a new understanding of the places that are the valuable islands of remoteness within that

**Fig. 7.4** Gridded cartogram of travel times to the nearest city over 50,000 population in Europe (Own depiction by the author using data from CIESIN and CIAT 2005; Hengl 2011; Nelson 2008; NOAA 2009; USGS 2009)

region. In some countries these are more, in others they are less remote, as the gridded country cartograms of travel times show.

The remotest places of Europe increase in size the further north one travels (Fig. 7.4). The southern regions mainly turn into remote areas where the terrain rises higher and the populated places dominate less of the landscape. Iceland is an island of remoteness in itself, with only its capital Reykjavík fulfilling the criteria for a major city. On the world map it is hard to see because much of the island is well connected only by a major ring road that circles around the island, but when changing the focus on Europe, it can be seen how the changing scope reveals different details and creates new understandings at different scales.

Even within the densely populated areas of Western Europe there are still some striking differences. The British Isles as part of the larger very populated regions in Europe show the dominating distances that increase the further north you come in Great Britain (Fig. 7.5). Furthermore, the relative remoteness of much of Wales can be seen, and the *Emerald Island* of Ireland shows up largely as a refuge of more natural environments where large parts of the island outside the major urban areas of Dublin and the slightly more densely populated northern region feature prominently in the transformed grid.

Europe's most populous country, Germany, shows a more even pattern with relatively remote rural areas and the urban centres being spread across the map (Fig. 7.6). It reflects the more even population distribution and is also a picture of a more balanced urban system in the country. The largest urban centres appear as nodes that

**Fig. 7.5** Gridded cartogram of travel times to the nearest city over 50,000 population on the British Isles (Own depiction by the author using data from CIESIN and CIAT 2005; Hengl 2011; Nelson 2008; NOAA 2009; USGS 2009)

are often connected to each other via denser lines of less remote grid cells where grid lines seem to converge like a network of people across the country, with the most distant places in the country bulging out between this human cobweb.

The examples of gridded cartograms for remoter places show how different the emerging patterns become at various scales, and how well they create complementary understandings of the geography of the world, a continent, or a country.

Gridded cartograms can create a new image of the physical environment, which adds cartograms to the range of visualisations that can be used beyond the scope of merely socioeconomic issues. The resulting maps provide valuable new insights into the physical geography of the world and make quantitative data gathered from the environment more comprehensible without losing their geographical reference and accuracy. The visualisation created here can be useful for conveying quantitative geographical data in an understandable way to the public (e.g. shown in Holmes 2011), but may also be of further academic value as they can also provide new understandings of the patterns that the physical environment creates.

With the preservation of geographical references in the grid, a gridded cartogram is a novel type of geographic projection that is based on a replicable mathematical operation that turns the land area into spaces of equal quantities of any measurable

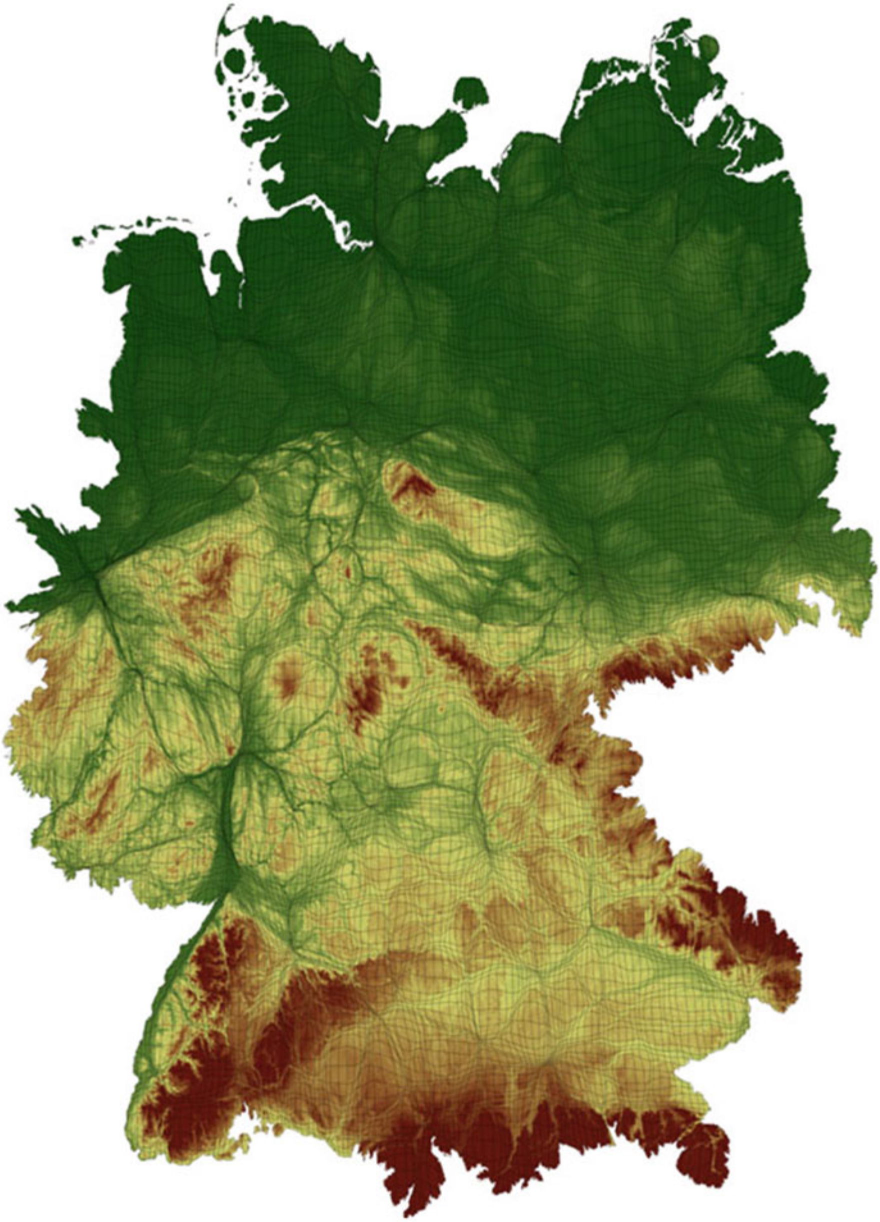

**Fig. 7.6** Gridded cartogram of travel times to the nearest city over 50,000 population in Germany (Own depiction by the author using data from CIESIN and CIAT 2005; Hengl 2011; Nelson 2008; NOAA 2009; USGS 2009)

(or countable) topic. As presented here, gridded cartograms provide a serious alternative to traditional mapping methods.

## 7.5 Discussion

Global spaces of remoteness and inaccessibility are the last refuges of wilderness that are not untouched by humankind, but that are the precious places where we preserve some of what the world was like before we started making it the human planet (Steffen et al. 2011). While these spaces are in decline, the most remote areas are only a fraction of our land surface that we see in conventional maps. Cartograms can provide a powerful visualisation tool that provides the base to redraw the geography of the planet in diverse ways and to highlight these diverse natures of the world.

The constraint of arbitrary administrative boundaries that usually build the base for a cartogram transformation does not exist anymore in the gridded cartograms. The high resolution and good quality of the now existing global datasets of a wider range of issues related to human activity provides a solid base for this geographic transformation.

Visualising spaces of wilderness as demonstrated with the concept of global accessibility can be achieved in manifold ways. Beyond the conventional mapping approaches that are normally used, the use of a gridded world population cartogram as a basemap highlights the relative accessibility of people on the planet. It demonstrates that some parts of the world's population are less accessible than others and which matters in a world that increasingly depends on global links and interrelations.

The human space in the centre of the map projection shows the dominating spatial element of what has recently often been described as the Anthropocene. But this is only one way of transforming space and looking at the dimensions that shape our planet. The general methodology can be extended even further and provide novel ways of visualising any quantitative geospatial data in cartographic ways.

Global accessibility itself can be converted to a quantitative measure that can be applied to the grid cells as the basis for a cartogram transformation, as demonstrated here with the least accessible spaces. After the actual transformation, these spaces reflect the inaccessibility, as longer travel times to get to an area result in an increased the size of the corresponding grid cell. Conventional map projections limit the range of visualisation methods that are suitable to show quantitative data. In a plane two-dimensional map, this can be done in choropleth form with distinct colour schemes (Fig. 7.1), but these have the disadvantage to require a rather abstract translation of the colours into a third dimension of quantities.

3D visualisations provide an alternative, but therefore have to be interactive or require a number of several individual perspectives to be able to understand the third dimension in a two dimensional form (on paper or on screen). The use of graphs and charts in contrast loses the advantage of a map as a direct geographical reference.

The gridded cartogram technique can provide an alternative solution to this problem that retains a very high geographic accuracy in the grid but makes the quantitative dimension visible in the changing sizes of the grid cells. The emerging patterns retain the geographical reference, but can become more abstract. The more unusual patterns, however, create a unique vivid appearance of the displayed topic and open a new dimension of understanding the large amount of underlying data.

Gridded cartograms created from geospatial data are not a single new map projection, but a technique that makes geographically relevant topics from the physical and social world come alive and thus represent a multitude of unique map projections. The gridded cartograms have the potential to create a different understanding of the real extent and impact of a geographical topic. They may be more unusual and still unconventional, but provide alternative ways of geovisualisation while retaining core cartographic elements of spatial representation.

Crucial for the further application of gridded cartograms are the underlying datasets. Data for the gridded cartograms must not have any gaps but have to be complete over the entire grid covering the area of interest. Only then can one create a coherent and valid transformation that does not result in a misleading representation. That is crucial for any cartogram, as gaps in the data cannot be dismissed like in a conventional map. Therefore the creation of gridded cartograms requires a high effort, which is often greater than that of other cartograms where only a limited number of data values is needed for the transformation.

With huge advances in data availability in recent years, and with growing demand for gridded data in scientific modelling, these datasets have become increasingly available and do not always need to be created. Therefore, this alternative way of visualising them provides a great opportunity to enhance the understanding of these complex datasets in the different scientific domains.

For research on wilderness and remote areas, global accessibility therefore is only one concept that provides a suitable quantitative dataset that can be applied to a gridded cartogram transformation. Wild spaces have a multitude of expressions. (In)accessibility is an issue that is closely linked to human activity, while some other areas of research may be less interested in the accessibility, but in other indicators that define a wilderness area. The range of potential applications therefore is large and mainly requires a creative and unconventional approach to data preparation.

The gridded cartogram technique is still a time-consuming approach that requires a lot of effort in pre-processing and transforming the data. Tools that simplify the methodological effort will have to be developed to make this process easier. Processing times are another crucial issue. But with increasing computing capabilities and with more data resources becoming available, this is likely to become more straight-forward in the forthcoming years. A clear objective must be the simplification of the method to implement it in common workflows of visualising geospatial data.

The concept of creating new gridded data beyond mono-thematic quantitative data by combining data sets, like the calculation of travel times from a range of indicators of the physical and social environment, demonstrates the benefit that new unconventional approaches can have. Much scientific effort is put into the creation of indices and similar models that often also bridge the gap between human and physical geography. Global accessibility does not look at either one or the other side but aimed at getting understandings of the different interrelations and connections and see how they create new patterns and shapes of humankind. But why stop there and not think further also for the visualisation of such data: Wilderness areas are the last spaces of the wild. Why not rediscover these hidden gems by looking at them in new ways?

## 7.6 Conclusion and Outlook

This chapter presented a visualisation approach using cartograms as a way to visualise spaces of global inaccessibility. The result are maps of the remotest parts of the planet that add that dimension of (in)accessibility visually to the map while preserving some key features that characterise conventional map projections. The results are not only geographically accurate depictions of the underlying data, but are also scalable to show global, regional and national variation within the data.

Adapting the famous expression commonly used in conjunction with pictures, the examples outlined in this chapter show that *a map is worth a thousand words*. Techniques of geographic visualisation can be a useful tool to translate complex ideas into thought-provoking images where the traditional idea of a map does not always have to be the concept for a spatial data visualisation.

The maps presented here are a novel approach of using cartogram transformations for the visualisation of quantitative data not only related to the social dimensions, but also with a direct relation to the diverse physical environments that shape our perception of the planet. The concept may not be useful for all applications and studies of wilderness, but it extends the range of techniques that we can use to provide different perspectives on the remotest spaces of the planet.

Gridded cartograms mark a new way of utilising cartogram creating techniques at various scales. The geographic reference to the physical space is kept in the cartographic transformation, allowing other information to be transformed alongside the defining indicator of the actual cartogram. The examples in this chapter demonstrated that this unique characteristic of gridded cartograms is a key element to enhance the value of the analytical and visualisation capabilities of cartograms and make them similar to an unusual but powerful map projection that gives us a different understanding of the relation between the cartogram and any other layers that are mapped with it.

The range of potential application for these maps is only limited by data availability and thematic areas of interest – and one's imagination. Instead of using topographic information as in the maps presented in this chapter, possible uses could highlight topics ranging from biodiversity, environmental risk factors to human activity in these remotest places outside the direct range of humanity. While these maps show the most inaccessible spaces on the land surface, such visualisations can be one way of highlighting the threats affecting even these remote areas. Where performed accurately, gridded cartograms have the capability to function like a magnifying glass over the key area of interest, which in many cases is omitted in conventional map projections, while at the same time preserving the geographic accuracy of the information that they contain.

No map projection is perfect. Sometimes it can be helpful to be more creative and think outside the box of cartographic conventions that we have learned to accept as normal over the decades and centuries. Today's world is different than that of the times when many of our cartographic techniques were developed. We live on an ever-changing planet where the interrelation between humans and their environment has become one key element that shapes it. To understand these changes, we have to change our perspectives and to find new ways of understanding these complex spaces.

Gridded cartograms are not perfect either. First and foremost they are still time-consuming pieces of work that require a lot of effort in their production. Once the underlying data has been obtained or generated, the real work of adjusting and transforming it starts. Putting these technical obstacles aside, they are unusual yet striking representations of the spaces that are hardest to get to. They provide one more way of seeing the world beyond the box of maps we normally use.

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