GIMA
Geographical Information Management and Applications

Visualising boundary disputes on the map objectively?

Providing a framework for applying uncertainty visualisation to map disputed boundaries in a as objective as possible way

Master's Thesis – Final Report

Author:
Guido Mosch
5932068
g.mosch@students.uu.nl

Supervisor:
Prof. dr. Menno-Jan Kraak

Responsible Professor:
Prof. dr. Raúl Zurita-Milla

03-03-2022
Utrecht

Preface

I am proud to present to you my master's thesis on the visualisation of disputed boundaries as objective as possible through the application of uncertainty visualisation methods. This thesis is part of my master's degree Geographical Information Management & Applications (GIMA).

Having chosen this subject, I was immediately enthusiastic about combining cartography with political geography, which has been an avid passion of mine. My supervisor Menno-Jan was as, or maybe even more, passionate on this subject as I was. But I was also warned. Menno-Jan told me that visualising disputed boundaries with the goal of objectivity was a tough one, one of which other cartographers argued is doomed to fail. At the end though, I present you a framework into possible visualisations that can be further explored. As we move away from paper atlases and start going into online applications, new possibilities can be explored.

Though I wrote this thesis by myself, I would like to thank Menno-Jan for keeping me motivated throughout the process of writing and helping me out with his expertise. Furthermore, I would like to thank Raúl Zurita-Milla for fulfilling the role of responsible professor for this research. A final thanks goes out to friends and fellow GIMA-students that supported me during the time period of this research.

I hope you enjoy reading this research as much as I have enjoyed researching it.

Yours truly,

Guido Mosch

Abstract

Territorial disputes and conflicts still define today's news headlines. As of February 22, 2022, Russia recognises two self-proclaimed independent states that the rest of the world considers to be part of Ukraine. The situation of Luhansk and Donetsk show that the world is still as geopolitically tense as ever. Cartographers get tasked with visualising the area from different perspectives. One perspective prescribes to visualise the areas as two new countries, whereas another perspective prescribes to show the two areas as part of Ukraine, but with something going on to inform viewers on the current situation. This only shows how relevant the work of a cartographer is, still today. The visualisations determine how people from different parts of the world view the areas from different perspectives. How to visualise these disputed territories, as well as other disputed boundaries, is what the goal of this research is. However, the goal of this research is not to do it from different perspectives, but to visualise the disputed boundaries as objective as possible. To do so, this research aims to answer the following research question: *"How can geopolitically disputed boundaries be visualised as objective as possible on a map?"*

To answer this research question, a theoretic framework on geopolitically disputed boundaries had been created. Here, the distinction between two types of disputed boundaries had been made. On one hand, disputed boundaries can exist as two states do not agree on the location of it. On the other hand, disputed boundaries can exist as one or more states do not recognise the boundaries of another, self-proclaimed independent state, and view the boundaries as illegitimate. Following this an extensive analysis of atlases and online map environments have been performed to gather insight on the current visualisations of disputed boundaries. Based on this and on existing literature on uncertainty visualisation, different visualisations have been created in a web application to discuss during expert interviews. These experts have been selected on their knowledge and experience with cartography. Some experts had direct involvement with disputed boundaries or the visualisation of those.

Based on the analysis of atlases, online map environments, uncertainty visualisation methods and the interviews, it is found that colour hue and polyline shape improve the map readability. Colour hue should be applied to show the claims of different countries. The shape of polylines should be used to define whether an accepted or disputed boundary can be seen. Moreover, it is found that transparency is the best fitting option for claims in maritime areas, especially in the South China Sea where 7 parties are involved. Having maritime claims as transparent layers helps pinpoint each of the claimed areas. For disputes between two countries over larger areas, it has been found that hatching is still the best suitable visualisation method, as viewed by the experts. Using colours for hatches makes the map understandable in a one-eye view, which is deemed an important factor of map readability. A final recommendation is made on the jagged line technique, which would require more testing with non-experts to verify the understandability and suitability of it. The jagged line technique should be combined with polyline shapes to signify its disputed status.

Table of Contents

I. List of Abbreviations

BRO – Base Registration Subsoil (Basisregistratie Ondergrond)
EEZ – Economic Exclusive Zone
EU – European Union
GDP – Gross Domestic Product
NATO – North Atlantic Treaty Organisation
PDOK – Public Services on the Map (Publieke Dienstverlening Op de Kaart)
Polisario – Popular Front for the Liberation of Saguia el-Hamra and Rio de Oro
SQ – Sub-question
UN – United Nations

1. Introduction

'Agreeing to not agree' has been the outcome of an ongoing boundary dispute between Germany and the Netherlands over the Ems-Dollard estuary (Van der Werf, Gilissen, Kleinhans, & Van Rijswick, 2020). While both countries leave it as it is, cartographers are faced with an issue: Where exactly do you draw boundary line between the two countries in this area? It is a cartographic problem that mapmakers have swept aside, marking the boundary line as 'disputed' in an atlas, map, or online mapping environment. Boundary disputes occur all over the globe and are not always as peaceful as the boundary dispute over the Ems-Dollard estuary. A boundary dispute between India and China over the Galwan Valley, located in the Jammu & Kashmir region, escalated in 2020. Both countries accused the other of crossing the boundary and instigating a fight. The fight resulted in the death of 20 boundary guards (Goldman, 2020, June 17). The example of the Galwan Valley shows that boundary disputes can be politically tense and even have deadly consequences. This makes the task of a cartographer even harder because how the boundary is visualised, albeit disputed, results into the disagreement of one or more parties involved in the dispute. Drawing the boundary in the Galwan Valley as China says, will result into a protest by India. Drawing the boundary in the Galwan Valley as India says, will result into a protest by China. Drawing the boundary in the middle of the two claims, will most likely result in the protest of both countries. Therefore, one must ask: How can you map a boundary dispute as objective as possible?

This goal of this research is to propose a framework for mapping boundary disputes as objective as possible. Note the terminology being used is 'as objective as possible' as it can be argued that boundary disputes cannot be mapped entirely objective. Having considered existing methods of visualising disputed boundaries, this research intends to explore the application of uncertainty visualisation for the mapping of disputed boundaries. This visualisation approach has been systematically introduced by MacEachren (1995), see also his further research on the topic of uncertainty visualisation (MacEachren et al., 2005; MacEachren et al., 2012).

1.1 Scientific Relevance

There are numerous scientific literatures written about boundary disputes (Amupanda, 2021; Anderson, 1993; Borgen, 2010; Gerrits & Bader, 2016; Hong, 2013; Jackson, 2004; Karalekas, 2020; Rowan, 2005; Tuathail, 2008; Van der Werf et al., 2020; Zajc, 2019). However, all these literary works are descriptive in nature. A few works include maps of the area, but none of these maps are about an objective visualisation of the boundary dispute, the maps just provide historical background. Here, 'objective' should be read as showing no favouritism to either side of the conflict. There are a few works about specifically visualising disputed boundaries. Darques (2016) noticed that the boundaries of former Yugoslavian countries change per map he analysed. He proposed a method of generating one definite boundary through an algorithm that analyses the different locations of the same boundaries. Zhang (2016) combines the use of uncertainty visualisation with disputed boundaries in her master's thesis. Her goal wasn't to strive for objectivity, but to inform map readers of temporal changes found at boundary disputes.

This shows that, despite the abundant knowledge on boundary disputes, there is a lack of research on how these boundary disputes should be visualised in an objective way. A scientific debate about this subject is rather absent and this research will help to start that debate to improve the standards of maps. Furthermore, this research is scientifically relevant in the debate on uncertainty visualisation methods. Uncertainty visualisation can be done through various methods and it is claimed that there is not one specific right method, it dependents on the case (MacEachren et al., 2005). This research will elaborate on that knowledge and therefore add onto this scientific debate.

1.2 Societal Relevance

The societal relevance in this research lies with creating a more objective version of a world view. The framework for visualising disputed boundaries is supposed to provide the readers of maps and atlases with more information on the geopolitical situation occurring at certain national boundaries. This becomes clear when comparing the National Atlas of India (Nag, 2003) with the Times Comprehensive Atlas of the World (Times Atlases, 2007). Whereas the National Atlas of India portrays Aksai Chin and the Karakorum Range to be Indian, the Times Comprehensive Atlas of the World portrays it as being disputed between India, China, and Pakistan. People who base their world view on either atlas have thus conflicting ideas of how the countries in the world look like. This is similar to the recognition of countries. De Grote Bosatlas (Noordhoff Atlasproducties, 2012), an atlas widely used in the Dutch public school system, portrays Kosovo as an independent country. Contrary, The National Atlas of Georgia (Bolashvili, Dittmann, King, & Neidze, 2018) portrays the area of Kosovo as part of Serbia. It can be assumed that this results into different world views as well. Based on either atlas, the reader would not know that the area is contested due to different political views on the independence of it. Furthermore, the reader does not know how contested the existence of the country is. The proposed framework in this research helps clarify each of the above explained issues currently existing in atlases, maps, and online map environments.

1.3 Research Objectives

As it has been argued, the scope of this research will be focused on disputed, national boundaries and how they can be visualised by the use of uncertainty analysis. The goal of this research is to provide a framework that can be used to visualise boundary disputes on the map in an as objective as possible way. This will be achieved by finding an answer on the research question that stands central in this research:

"How can geopolitically disputed boundaries be visualised as objective as possible on a map?"

Four sub-questions (SQ) have been drafted to answer this research question.
SQ1: "What kind of geopolitically disputed boundaries exist?"
SQ2: "How do current maps visualise disputed boundaries?"
SQ3: "In what way can uncertainty visualisation be applied to visualise disputed boundaries?"
SQ4: "How to formulate and evaluate a visualisation framework for boundary disputes?"

1.4 Research Limitations

This research only focuses on disputed national boundaries. To clarify, this research defines national boundaries as boundaries of a sovereign country that is recognised by at least one member of the United Nations (UN). To provide an example, Georgia would contest South Ossetia having national boundaries. However, as five UN member states recognise South Ossetia as a sovereign state, it is included in the scope of this research. On the other hand, the Republic of Artsakh is not recognised by any of the UN member states as a sovereign state. Therefore, the boundaries are not considered national in this research. The republic of Artsakh thus lies outside the scope of this research.

Another limitation of this research should be understood, which is that this research presents a method of visualising the boundaries as objective as possible. Full objectivity cannot be achieved, it is stated to be widely understood that GIS does not present a value-neutral view of the world. However, it is possible to provide a formal framework to reconcile different world views (Rosentrater, 2015). Not only GIS, but also the author, interviewed experts and others involved in this research might unintentionally influence the objectivity of this research due to their bias, past

experiences, and own world view. This research should therefore be seen as an attempt to be as objective as possible, rather than posing the one and only solution to the problem of visualising disputed boundaries objectively.

2. Boundaries

2.1 Theoretical Framework

'That which serves to indicate the bounds or limits of anything whether material or immaterial, also the limit itself' is the definition of a boundary by the Oxford English Dictionary ("Boundary", n.d.). By this definition, a boundary indicates an ending of phenomena at a certain line. This is a rather broad definition that requires deconstruction. Figure 2.1 provides a theoretic framework to define boundaries. The following paragraphs will elaborate on a certain aspect of this framework. The grey boxes provide examples for each of the boundary-related concepts.

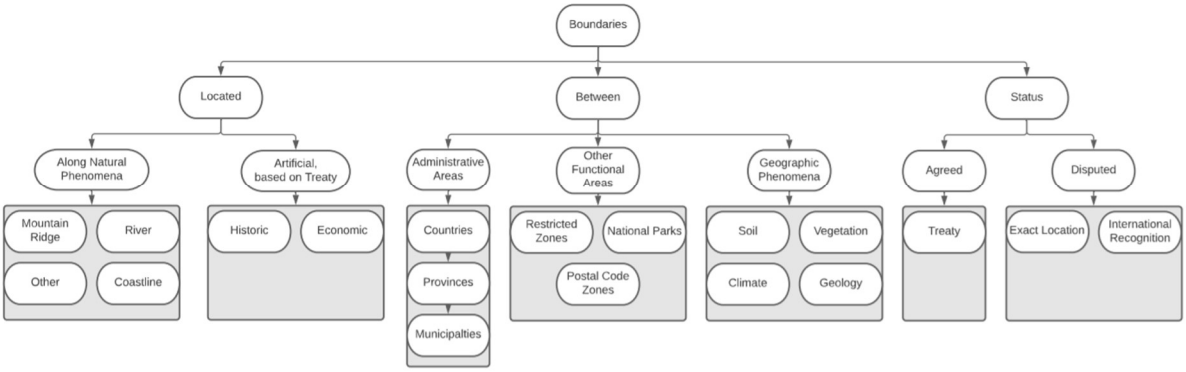


Figure 2.1: Theoretic Framework of Boundaries

2.2 Location-based boundaries

In the classic geopolitical view, a political boundary can be divided into two types of boundaries: natural boundaries and non-natural boundaries (Van Houtum, 2005). Natural boundaries are located along natural phenomena, such as mountain ridges, rivers, and coastlines. Non-natural boundaries are artificial, these boundaries have been laid down for historic or economic reasons. This division on location-based boundaries is not limited to only a geopolitical view. Other type of boundaries, i.e., of vegetation of precipitation, are also located along natural phenomena. This will be elaborated upon in the following paragraphs.

2.2.1 Along Natural Phenomena

Mountains are influential on the climate and precipitation of the area. For example, Kerkhoven and Gan (2011) state that the precipitation in the Rocky Mountains is much higher on the windward side of the mountains, compared to the leeward side of the mountains. This impacts the climate zones on both sides of the mountains, as there is much more water runoff on the windward side, while the leeward side is a relatively much dryer place (Kerkhoven & Gan, 2011). This then also affects the vegetation on both sides of the mountain. Figure 2.2 shows the Andes mountains (dark purple line) in Latin America. The mountain forms a clear boundary between the moist forests (green) on the east and the dry forests and steppe (red and light purple) in the west. Mountains can also form boundaries between countries, most often based on the ridge of the mountain. France has been formed alongside the Pyrenees and Alps as natural boundaries and the Himalayas and Karakorum Range provide a natural boundary between China on one side and India, Afghanistan, and Tajikistan on the other side (Marshall, 2016).

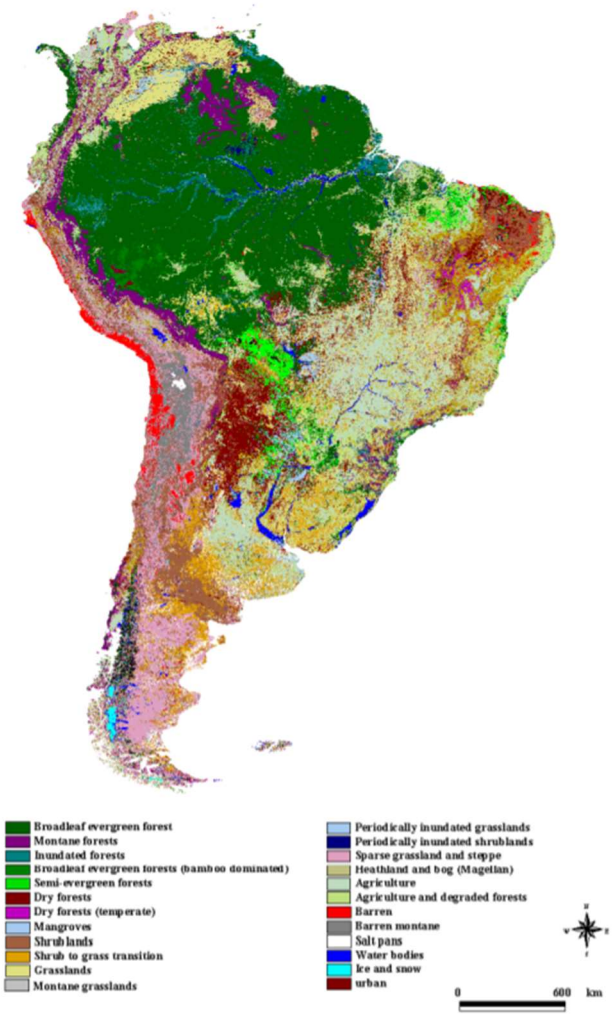


Figure 2.2: Vegetation map of Latin America (Eva et al., 2002).

Coastlines are an indication of the end of the land and the start of water and were therefore a popular boundary for countries. Invaders would have to enter through either air or water, which gives the defensive side the advantage. Perhaps the most famous example of a coastline boundary is that of Germany during World War II. The coastline formed a natural boundary between it and the allied forces on the other side of the oceans. To defend this boundary, the Germans build the Atlanktikwall, an extensive line of concrete fortifications. This fortification ran from the beaches of France at the Atlantic Ocean to the Norwegian coast at the Barents Sea (Stamatiou & Lacroix, 2008). Coastlines also form the base for Economic Exclusive Zones (EEZ). The EEZ is a zone of 200 nautical miles into the ocean of which a country has the monopoly to freely control the resources inside. The EEZ is part of an international law set up by the UN in 1982 (Andreone, 2015). Aside from political purposes, coastlines also indicate boundaries between different geologies and surfaces. Cliffed coasts are an example of a clear boundary between the land and the sea surface. However, this difference is not always that clear. It is harder to determine the land and the sea surface for shorelines coasts susceptible to changing tides.

Rivers are a form of a natural boundary, as the water splits the land, resulting in multiple separate areas. According to Popelka and Smith (2020), rivers make up to about 23 percent of all international boundaries. This is the most in Latin America, where nearly half of the international boundaries are based on rivers. The rates are also relatively high for North America (28 percent), Africa (26 percent)

and Europe (21 percent). The relatively high percentage in Latin America and Africa is because of European colonisers. European explorers, politicians and cartographers found it easier to divide countries based on rivers. This might explain why only 16 percent of Asia's international boundaries are rivers, as the European influence was limited to the coastal areas of South Asia, Southeast Asia (Popelka & Smith, 2020) and the Middle East. The Roman empire already used rivers as boundaries for its empire. The Rhine and the Danube River marked the northern boundary of the Roman empire over 2000 years ago. Later, the river formed the natural boundaries for the Austro-Hungarian empire and the Ottoman empire. Nowadays, the Danube basin still marks natural boundaries between Slovakia and Hungary, Croatia and Serbia, Serbia and Romania, and Romania and Bulgaria (Marshall, 2016). A full list of modern-day river boundaries is provided by the IBRU Centre of Borders Research (IBRU, n.d.).

Coastlines and rivers are natural phenomena exposed to change. Sand erosion due to heavy weather and beach constructing caused 2430 hectares of beach to be lost each year in the US during the eighties (Charlier, Chaineux, & Morcos, 2005). Rivers change mostly due to geomorphological characteristics, i.e., meandering, dead river branches, and gravel bars (Zajc, 2019). Due to these changes, boundaries along these natural phenomena may change as well. While mountain ridges are also naturally exposed to change, i.e., plate tectonics and erosion, the pace on which this change occurs is too slow to have a direct impact on the boundaries based on the mountain (ridge).

While mountains, coastlines and rivers seem to be the most prevalent natural boundaries, there are also boundaries based on other natural phenomena. The Gobi Desert between China and Mongolia is such an example. Marshall (2016) states that the natural boundary is easily defendable for China and not likely to be crossed by Mongolia. An army would be spotted weeks in advance and the inhabitable area would require incredibly long supply lines for an attack (Marshall, 2016). The latter also applies vice versa, which means that over time a boundary between the two countries has been established as neither China nor Mongolia would be able to extend it.

The distinction between natural boundaries and non-natural boundaries became connected with the terms 'good' and 'bad' respectively in the geopolitical discourse. According to Van Houtum (2005), natural boundaries of states resulted into more culturally homogenous states. Before states were created, boundaries of cultures were already located along natural phenomena These boundaries were difficult to cross and easier defendable and thus kept one culture inside and other cultures outside. Basing boundaries of a new state on those same boundaries, would therefore result in more culturally homogenous states. Creating new, artificial boundaries, not along natural phenomena, results in a mix of different cultures and/or the splitting of a culture into multiple states, resulting in cultural heterogeneity. These terms 'good' and 'bad' also relate to the wealth and welfare of a state. A study in 2006 confirmed the widely believed theory that these 'bad' boundaries are associated with lower per capita GDP, greater political instability, and poorer life quality overall (The Atlantic, 2006, as cited in Fall, 2010). A 'good' boundary is therefore deemed to have a positive impact on the welfare and wellbeing of the regions/countries it divides.

2.2.2 Not-Along Natural Phenomena

Economic boundaries can be best found in Africa. Though the continent is most known for straight, or artificial lines as boundaries, these boundaries are not as arbitrary as they seem (Green, 2012). Africa's boundaries are drawn by European colonisers, politicians, and cartographers. While almost a fourth of the boundaries are based on rivers, 44% percent of the international boundaries of Africa are artificial lines (Green, 2012). It is found that these boundaries are based on pre-colonial population density and pre-colonial trade routes. Green states that these boundaries are the result of "rational revenue-maximising decisions" (2012, p. 240).

The previously discussed EEZ is based on a natural boundary, but the extent of it is not. Starting from the coast, a state has a 12 nautical mile zone which is referred to as the 'territorial sea'. These waters are directly part of a state and thus fall under their jurisdiction. Following the territorial sea is the contiguous zone, which is another 12 nautical miles. The EEZ is 200 nautical miles, adjacent to the territorial sea. This means that the EEZ overlaps with the contiguous zone. The EEZ gives the exclusive economic right to the sea, the surface, and the subsoil located in that area (Freestone & Schofield, 2016). Aside from the right on the resources, states also gain the responsibility of the resources. The state is obliged to ensure that resources do not become overexploited, leading to the endangerment of the living resources inside the EEZ (Couper, 1983). The EEZ is thus based on a state's coastline, but with economic intentions, as the 200 nautical miles are not based on natural phenomena.

2.3 Separating Boundaries

As the location of boundaries has been discussed, it should also be addressed where the boundaries find themselves between. As the definition of a boundary goes: it indicates a limit, or end. Therefore, a boundary acts as a separation between limits or ends. Three key separators have been identified in the theoretic framework, which are administrative, other functional, and geographical. The first two are between man-made constructs, whereas the third is between natural phenomena.

2.3.1 Administrative Boundaries

Administrative boundaries hold the right to govern the area, for example by implementing laws and collecting taxes. Administrative boundaries are found on different scales, which includes a form of hierarchy. It is important to show that these different scales should not be seen as separate, but as interconnected (Flint, 2017). The theoretic framework in figure 2.1 provides an example of the Dutch hierarchical administrative boundaries in the simplest version. Different states have different administrative hierarchies, which means that this is just one of many possible examples. While there are more scales involved in this hierarchy, the theoretical framework here is portrayed to stress the importance of scale and hierarchy when discussing administrative boundaries, not all the different administrative boundaries thinkable.

The Netherlands are divided up in 12 provinces and each province is divided up in a number of municipalities. A municipality always lies in only one province, so there is no overlap. Each administrative scale has its own government, but also falls under the government of the scale(s) above. This shows the interconnectedness Flint (2017) discussed. Aside from this hierarchy, there are also other administrative units related to the ones explained above. An example of this is the Dutch Water Boards. The Netherlands is divided into several Water Boards, these Water Boards are not limited to municipal or provincial boundaries. The Water Boards have their own unique boundaries that can overlap or be only partially inside a municipality or province. This makes this scale interconnected with both municipalities and provinces and cooperation with them is required.

Whereas these are the different scales of the Dutch administrative boundaries, other countries apply different scales. Martí-Henneberg (2005) mapped the different administrative boundaries of Europe throughout history. However, he notes that while doing so, he treats administrative regions as the same due to their similar sizes, while they are not the same in terms of governance. For example, Martí-Henneberg (2005) mentions that Swiss cantons and German provinces are different in governmental power, but are treated equally, nevertheless. Martí-Henneberg (2005) states that only the smallest scale, municipalities, would be approximately equal in governmental power. These observations show the complexity of administrative boundaries globally.

While the theoretical framework listed the national scale as the top scale, this is not true when looking at a global scale. The Netherlands is part of the EU and NATO, both intergovernmental organisations, with again its own regulations and rules.

2.3.2 Other Functional Boundaries

Administrative boundaries have the specific function of providing the right on governing an area. There are also other functional boundaries, sometimes government imposed, for which special rules apply. This chapter provides a few examples.

Government statistics make use of the administrative boundaries on a national, provincial, and municipal scale. However, these statistics remain rather broad. For a more detailed information, governments make use of postal code zones, such as Statistics Canada (Bow et al., 2004) and the Dutch Central Bureau for Statistics. Though originally designed for an efficient postal service system, it is now used as a low scale level on which statistical information is provided to the public. Figure 2.4 shows all the postal code zones in the Netherlands in 2020.

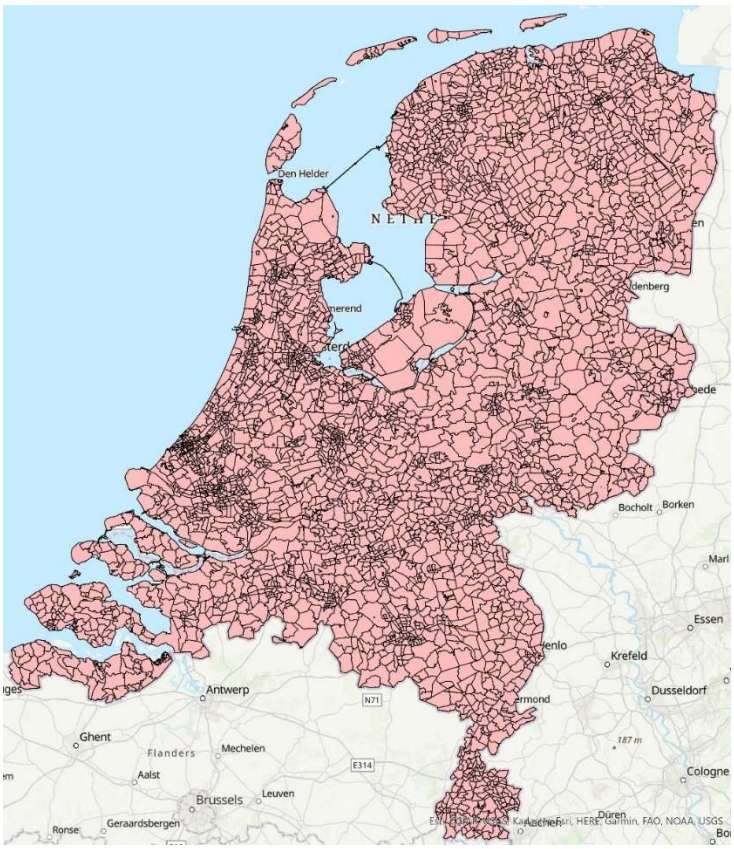


Figure 2.4: Postal Code areas in the Netherlands (PDOK, 2020)

Governments also impose restricted areas based on certain locational factors. For these areas, special regulation has been made. Figure 2.5 shows the no-fly zones for drones in the Netherlands. Special zones are marked, restricting the use of drones partly or entirely. The zones here are based on factors such as flying routes of airplanes, airports and natura2000 areas (Ministerie van Infrastructuur & Milieu, 2021). The boundaries on the map are rather clear, but they are not present in real life. The same applies to firework restriction zones or state or national parks. The boundaries in each of these cases can lead to difficulties as to knowing where exactly something starts not being allowed anymore.

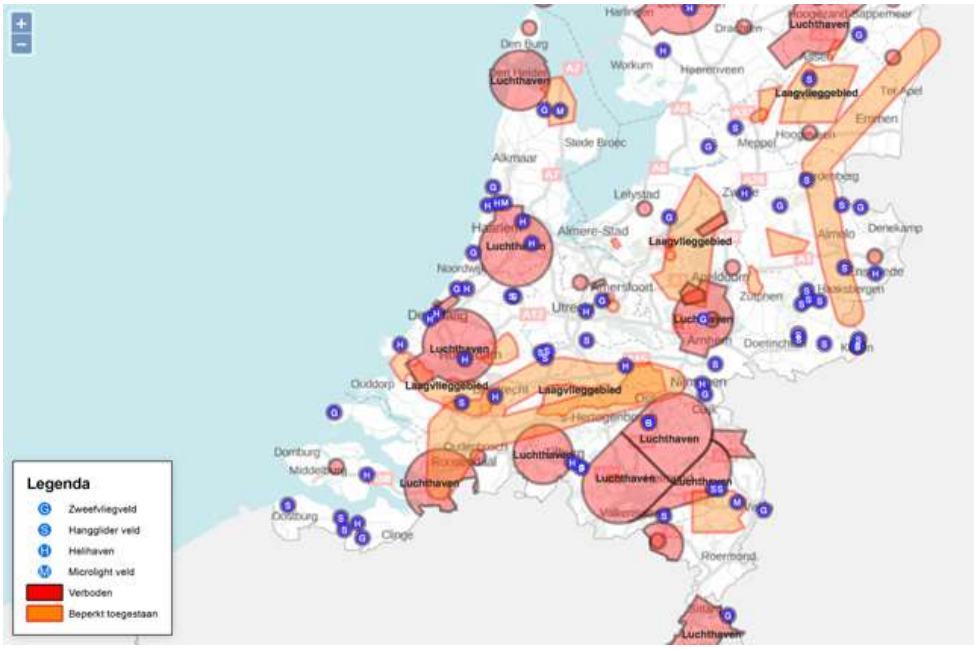


Figure 2.5: Snapshot of Drone No-Fly Zones (Ministerie van Infrastructuur & Milieu, 2021)

2.3.3 Geographical Boundaries

Geographical boundaries are rather different than the previous administrative and other functional boundaries. These boundaries are the result of natural phenomena, for example the location of soil, geology, climate, and vegetation.

Soil maps are the result of interpolated soil samples taken from an area. Soil samples are used to estimate the composition of soil at unsampled locations. Mapping these soil samples and interpolations results in a modelled map, in which there is some uncertainty on the exact soil composition at the unsampled locations (Carter & Gregorich, 2007). Figure 2.6 shows the most recent (2021) soil composition of the Netherlands. The map has a high number of classes and thus a high number of boundaries. When zoomed in, interpolation has resulted into clear boundaries (see figure 2.7). It should however be noted that though there are boundaries, the differences between them can be seen as minor. The soil dataset of 2018 has a total of 315 unique soil types. These have most likely been introduced to prevent sudden changes between soil types. This becomes clear when examining soil types that consists of clay and/or sand: 83 soil types include the word ‘clay’, 112 soil types include the word ‘sand’, and 5 include both ‘sand’ and ‘clay’. This means that there a are numerous classes between soil consisting of only sand and a soil consisting of only clay.

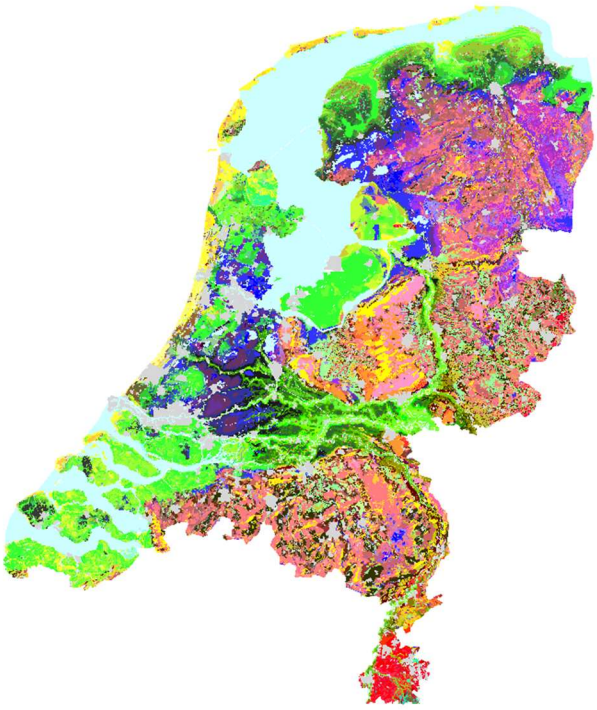


Figure 2.6: Soil Map of the Netherlands, BRO-Bodemkaart (PDOK, 2021)

Figure 2.7: Snapshot of Soil Map of the Netherlands zoomed in, BRO-Bodemkaart (PDOK, 2021)

Vegetation maps, briefly discussed in paragraph 2.2.1, also make use of boundaries in maps (Haslem et al., 2010; Jenkins & Frazier, 2010). Vegetation mappers most often make use of remote sensing technologies to accurately represent vegetation on the map, which results in certain vegetation boundaries. This method does not rely on samples and interpolation but relies on the quality of high-resolution airborne laser scanning. This method is faster than how soil samples are collected, for example. Haslem et al. (2010) provide a framework of vegetation mapping. The technology was found to be 67% accurate on average when validating their results with physically surveying the area. Jenkins and Frazier (2010) argue that there is an increasing need for higher resolution vegetation mapping. However, they also have stated that they have been successful in accurately mapping the boundaries of swamps and vegetation communities, see figure 2.8.

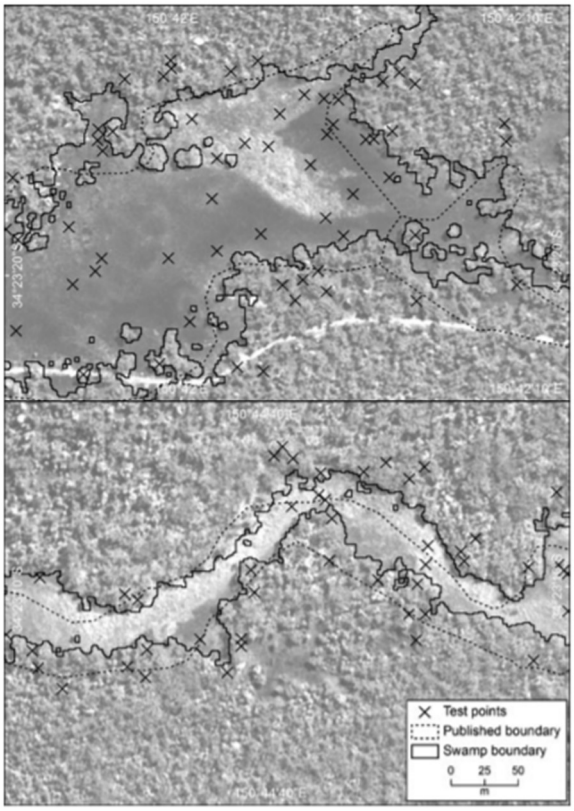


Figure 2.8: Swamp boundaries in Australia (Jenkins & Frazier, 2010, p. 535)

Perhaps the most known example of climate boundaries is the climate classification by Köppen-Geiger. The climate classes show distinct boundaries, though it can be argued that one would not immediately notice when crossing that same boundary in real life. A desert does not suddenly transition into steppe, for example. These climate classes aren't as elaborate as the soil classes. This means that boundaries on a map based on the climate classification by Köppen-Geiger show more coarse transitions. Figure 2.9 the Köppen-Geiger climate classification, adjusted for climate change (Kottek, Grieser, Beck, Rudolf, & Rubel, 2006).

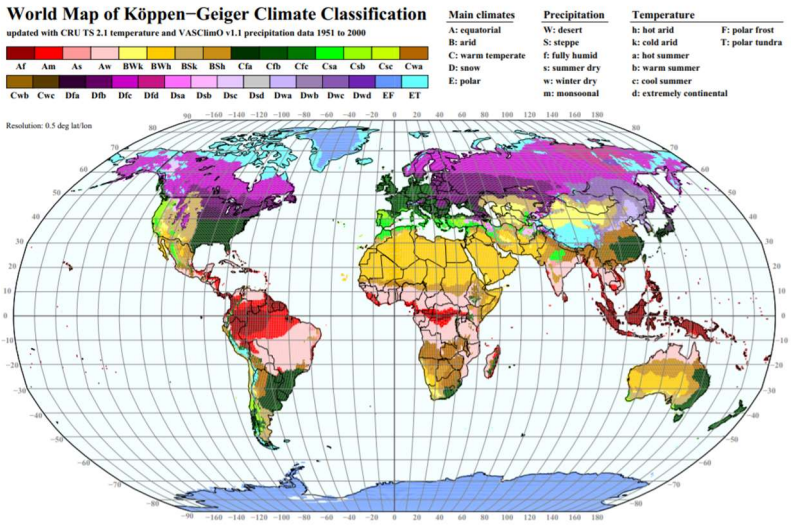


Figure 2.9: Köpper-Geiger Climate Classification (Kottek et al., 2006, p. 261)

2.4 Status of Boundaries

A final item to discuss from the theoretical framework is the status of boundaries. The status of boundaries mainly refers to the administrative boundaries discussed in paragraph 2.3.1. The status concerns whether the boundaries are accepted by all involved parties or whether they are disputed by some, or all involved parties.

2.4.1 Accepted

Accepted administrative boundaries are the result of common agreement. After negotiations, involved parties agree to where exactly the boundary is located, which is stated in a treaty. Treaties are settled to avoid further conflict and to settle on who gets the right to govern which area. This becomes clear from the first Russian-Norwegian boundary treaty, which was settled on the dispute on who got to tax the Lapps and Karelians in the 13th century (Jackson, 2004). As most of the administrative boundaries are accepted boundaries, there are arguably numerous examples like this.

2.4.2 Disputed

A disputed administrative boundary is the result of one or more involved parties not agreeing on the current boundary as it is. There are two main types of boundary disputes. Type I: The exact location of the boundary between countries is not agreed upon by those countries. Type II: The existence of a national, administrative boundary is not recognised as the self-proclaimed state is not recognised internationally.

The nature of boundary dispute type I lies mostly with the nature of the boundary itself. There are examples of boundary disputes of every factor identified under 'Located' in the theoretical framework in figure 2.1.

Though the Himalaya mountains form a natural boundary between India and China, both countries have an ongoing conflict over the exact location of that boundary. The Himalayan plateau is a strategic point as it is the access point from which India could invade China relatively easily due to favourable terrain. While India tries to gain control over the plateau to have an advantage against China, China wants to prevent becoming vulnerable and claims the plateau to be Chinese territory (Marshall, 2016).

Rivers are a source of boundary disputes due to the changing nature of rivers (Zajc, 2019). Zajc (2019) argues that administrative boundaries based on active riverbeds require communication and coordination between the two entities separated by that riverbed. A boundary dispute between Croatia and Slovenia has been a result of the changing riverbed of the Mura River, see figure 2.10. Since Yugoslavia split into different countries, it has been difficult to establish the definite boundaries of each state. Darques (2016) found that nearly each atlas or map had a different location of each boundary. A combination of old borders based on the Mura River that have lost relevance due to the meandering river and different interpretations of the historic boundaries have resulted in this boundary dispute (Zajc, 2019). The boundary now seems illogical and crosses the river at a multitude of points, making border patrol much more difficult. Other river boundary disputes exist over the fact on where exactly the boundary lies in the river. This is the case of the boundary dispute between South Africa and Namibia at the Orange River (Amupanda, 2021). While Namibia argues that the boundary is in the middle of the Orange River, South Africa argues that the boundary is located on Namibia's side of the riverbank.

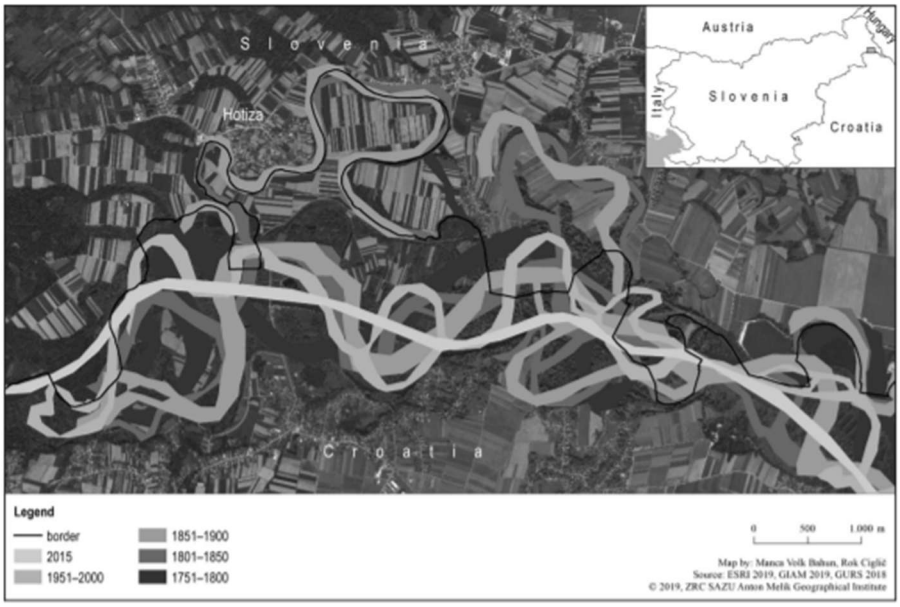


Figure 2.10: The Croatian-Slovenian boundary at the Mura River (Zajc, 2019, p. 383)

While the coastlines themselves do not lead to a border dispute, as there are no direct neighbours, maritime boundaries are a known source of boundary disputes. The Netherlands and Germany have a boundary dispute at the Ems-Dollard Estuary. The estuary falls within the territorial sea of both countries, which means that according to UN law, both countries must find an agreement themselves on where the exact boundary lays. The Netherlands and Germany have, however, not been able to come to an agreement on the location of the boundary and have agreed to leave the dispute as it is (Van der Werf et al., 2020). While this dispute is somewhat solved, disputes like these are still ongoing, for example in the South China sea (see paragraph 5.6)

Historical-based boundary disputes are often the result of post-colonialism. After the Spanish and Portuguese withdrew from Latin America, boundary disputes emerged all over the continent. These disputes were the result of a principle in international law, known as ‘uti possidetis’ that is used when new states are formed. This principle came into effect when the Latin American states became independent of their colonisers. There were however different interpretations of this principle. The former Spanish colonies applied ‘uti possidetis de jure’, which meant that a state took over a part of the territory Spain had, according to law and international agreements. The former Portuguese colonies applied ‘uti possidetis de facto’, which meant that a state took over the territory Portugal had, according to what Portugal had effective command of (Hensel, Allison, & Khanani, 2004). Due to overlap between Spanish de facto boundaries and Portuguese de jure boundaries, boundary disputes were inevitable. Though originally meant for Latin America, the ‘uti possidetis’-principle is used to review other boundary disputes as well (Hensel et al., 2004; Kumar, 2021).

The nature of boundary dispute type II is different, as it mostly lies with separatist movements inside another country. Separatists strive for independence from the state they are living in. The biggest driving factor behind separatism is nationalism, as the separatists do not feel like they belong to the nation they are living in. They either seek greater autonomy or even an independent nation for their own (Borgen, 2010). Some separatist movements are successful in creating a ‘de facto state’, also referred to as unrecognized state, pseudo state or separatist state. Often through warfare, de facto states have gained de facto independence, but lack international recognition (Caspersen, 2008). Somaliland, Tamil Eelam, Artsakh (Nagorno-Karabach) and Transdniestria are all de facto states without any recognition by UN member states. There are de facto states that have gained

recognition by a number of UN member states. For example, as of 2019, Kosovo has been recognised by 110 out of 193 UN member states (Bernabé-Crespo & Peña-Ramos, 2019). Other self-proclaimed states with partial recognition are Taiwan, Sahrawi Arab Democratic Republic (Western Sahara), Abkhazia, South Ossetia, Northern Cyprus, Donetsk, and Luhansk.

2.4.3 Temporality

The traditional take on boundaries is that they are long-standing, and therefore stable and static entities. However, critical border studies now challenge this idea (Little, 2015). As it has been argued, boundaries based on rivers are susceptible on change. There are then two takes on the boundary: 1) the boundary changes with the changing river, or 2) the boundary remains, while the river changes. An example of this is the case of the Maas River between Belgium and the Netherlands. A new treaty has been established to change the boundaries of both countries as the riverbed had changed as well. The changing river caused administrative issues for law enforcers, as now parts of the Netherlands could only be reached by crossing Belgium territory and vice versa. Adjustments to the shared boundary have been made so that this issue was resolved in 2016 (Koenders & Reynders, 2018). Not only are boundaries themselves temporal, but the view on a boundary is also temporal as well. This can be due to recognitions of states, which makes a once regional boundary become a national boundary instead. Another reason can be that a change takes place within the boundary dispute, resulting in a different view on that dispute as well. A change can be, for example, the occupation of an area or gaining administrative rights over an area.

2.4.4 Boundaries and the Scope

The framework discussed in this paragraph goes beyond the scope of this research. The framework has been provided to gain a cohesive understanding of the concept ‘boundary’ in a broader context than just ‘administrative boundaries’. This has been presented as these boundaries are also visualised on maps and should therefore be discussed when mapping other boundaries. From now on, the rest of this research will focus on administrative boundaries, specifically national boundaries. The scope specifically focusses on national boundaries with a disputed status. To understand the existing visualisation methods used for national boundaries, atlases and online map environments have been analysed. Such a methodology has been approached by Voženílek, Morkesová, and Vondráková (2014) whom analysed school atlases of 13 European countries to determine as to how international the symbology of school atlases were. This analysis is described in the following paragraph.

3. Analysis of current visualisations for national boundaries

42 atlases have been analysed to gain insight on the visualisations for both accepted and disputed, national boundaries, a full overview of all the atlases used can be found in Appendix I. Of these 42, 21 are national atlases, 10 are global atlases, 6 are school atlases and 5 are other atlases. Of some atlases, multiple publications have been analysed, these are included in the total of 42. The publication of these atlases ranges between 1970 and 2018.

The national atlases include a number of atlases of countries with specific interests in a disputed region, such as Chinese, Vietnamese and Georgian national atlases. Other national atlases have been included as well to see whether these national atlases take a side in the dispute or try to remain objective, such as national atlases of Japan, Panama, and Mozambique. Global atlases have been included to see how they visualise disputed boundaries, as it is expected that these atlases take a more objective stance on how the world boundaries are. School atlases have been included to specifically see how the world view is presented to school kids.

Next to the atlases, 14 online map environments have been analysed. A full overview of all the online map environments used can be found in Appendix I. 13 of these showed a global view of the world, only one focuses specifically on one area and its specific surroundings. Some of these map environments are from countries that have a specific interest in one or more disputed boundaries, such as Russian, Chinese, or Indian map environments. Other map environments have been included to see whether a side on a dispute is taken or whether they try to remain objective in the dispute, such as French, South African, or Turkish map environments.

For each of the map environments, the most current version has been used. Older versions have not been considered to get more insight in the current visualisation methods. The atlases already provide intel on visualisation methods of the past 50 years.

3.1 Atlases

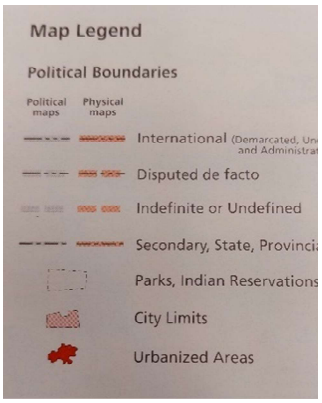
3.1.1 Accepted Boundaries

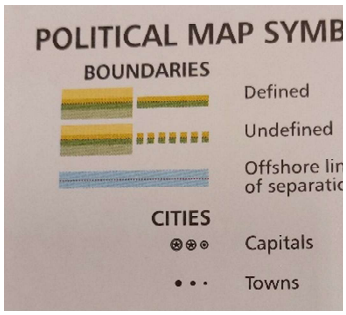
The symbology of accepted boundaries is consistent throughout most atlases. On a global scale, atlases make use of black lines to indicate accepted boundaries. On a map of a larger scale, the symbology of the atlas becomes more detailed. An accepted boundary is most often visualised as a sequence of black hyphens and periods, with a pink marking, see figure 3.1.

There are however some atlases that do this differently. The National Geographic Atlas of the World uses colours for different national boundaries. For example, all the boundaries of Ethiopia are green, and all the boundaries of Eritrea are orange. The shared boundary is then on one side green and on the other side orange. A sequence of periods indicates an accepted boundary indicates an accepted boundary, see figure 3.2.

Other atlases use the same sequence of hyphens and periods, but with a different colour for the marking or no marking at all. The Macmillan Centennial Atlas of the World uses a red marking, the Times Comprehensive Atlas of the World uses a purple marking. The National Atlas of Russia switches between a pink marking or no marking, see figure 3.3.

Other atlases make use of single-coloured lines, no matter the scale. Atlas Nacional de la República de Panama uses black lines, National Atlas of Ukraine uses purple lines, and The National Atlas of Georgia uses white lines.





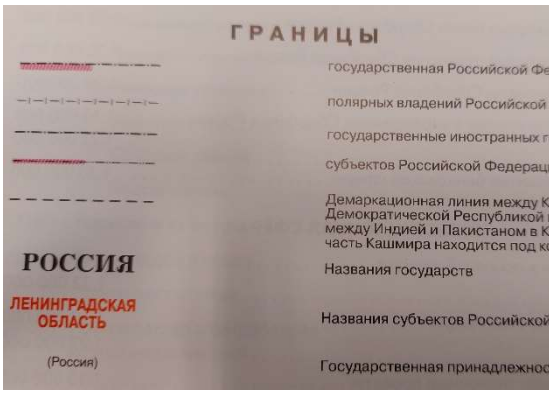


Figure 3.1 (left): Boundary symbology in Goode's World Atlas (Veregin, 2005)
Figure 3.2 (middle): Boundary symbology in National Geographic Atlas of the World (National Geographic Society, 2004)
Figure 3.3 (right): Boundary symbology in National Atlas of Russia (Kraiukhin, 2008) *(First entry in the legend is the national boundary)*

3.1.2 Disputed Boundaries

There are different types of disputed boundaries indicated in atlases. The most common method for indicating a disputed boundary is adding spacing in the line. In the case of coloured markings, there is spacing in between the colour, see figure 3.1 and 3.2. In the case of single-coloured lines, the line itself is separated by spacing, as if it becomes a sequence of hyphens only.

The Times Comprehensive Atlas of the World defines accepted boundaries as 'international boundaries' and differentiates between different several types of disputed boundaries. An internationally disputed boundary is described as 'disputed international boundary or alignment unconfirmed'. An internally disputed is described as 'disputed territory boundary'. Furthermore, the atlas also introduces visualisations for boundaries in specific cases: 'ceasefire line or other boundary described on the map', which is visualised by a sequence of purple periods before 2018, visualised by a sequence of purple periods with black periods in 2018, and 'UN Buffer Zone', which is visualised as a sequence of purple periods and a purple line underneath, see figure 3.4. This last boundary type has been introduced in 2018.

The National Geographic Atlas of the World shows disputed boundaries with spacing in between the sequence of periods. However, the atlas also shows red dots to visualise claims made by a state. Moreover, the atlas adds text to explain the boundary situation, see figure 3.5. The National Geographic Atlas of the World also makes use of diagonal stripes throughout an area, to indicate a different type of dispute. This is done in the areas of the Westbank and Gaza Strip, see figure 3.6.

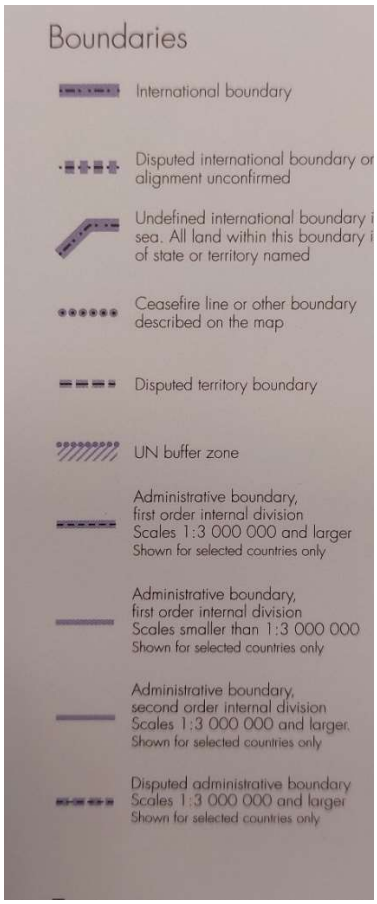


Figure 3.4 (left): Boundary symbology in Times Comprehensive Atlas of the World (Times Atlases, 2018)
Figure 3.5 (middle): Annotation in National Geographic Atlas of the World (National Geographic Society, 2004)
Figure 3.6 (right): Use of Hatching in Gaza and the West Bank, in National Geographic Atlas of the World (National Geographic Society, 1999)

3.2 Online Map Environments

3.2.1 Accepted Boundaries

Similar to atlases, most online map environments make use of single-coloured lines on a global scale. When zoomed in, these lines change into more detailed lines. ViaMichelin.fr uses purple lines to indicate an accepted boundary. However, when zoomed in, plus-signs are added into the line, see figure 3.7. The most common colours used are black, purple, or grey. The Japanese Yahoo! Maps is different, as it uses a sequence of grey hyphens with a purple shading, see figure 3.8.

Figure 3.7: Boundary as visualised on ViaMichelin.fr. Right is a zoomed in version of left. Symbology changes when scale is adjusted. (Michelin, 2021)

Figure 3.8: Boundaries as visualised on Yahoo! Japan. Left and right are two different boundaries. Left shows an accepted boundary. Right shows a disputed boundary (horizontal) and accepted boundary (vertical). (Yahoo! Japan Corporation, 2021)

3.2.2 Disputed Boundaries

Similar to disputed boundaries in atlases that used single-coloured lines, spacing is added within the line to indicate a disputed boundary, see figure 3.9. The Japanese Yahoo! Maps uses a red shading and shorter hyphens to indicate a disputed boundary, see figure 3.8.

A difference between online map environments and paper atlases, is that the online map environments are interactive. It allows one to zoom in, for example. Doing this on several online map environments, shows how scale matters on the importance of disputed boundaries. On ViaMichelin.fr, disputed boundaries become accepted boundaries when zooming in, see figure 3.10. More interesting, the boundary between Western Sahara and Morocco changes completely when changing the scale on the Thai online map environment 'Longdo Map' see figure 3.11.

Figure 3.9: Snapshot of Google Maps NL, disputed boundary between Venezuela and Guyana (Google, 2021)

Figure 3.10: Boundaries of the Abyei Area between Sudan and South Sudan, visualised on ViaMichelin.fr. Image on the right is a zoomed in version of the left image. The disputed boundary became an accepted boundary when zooming in, based on the symbology used. (Michelin, 2021)

Figure 3.11: Boundaries of Morocco and Western Sahara change when zooming in. Image on the right is a zoomed in version of the left image. (Longdo Map, 2021)

4. Uncertainty Visualisation

4.1 Visualisation & Symbology

Visualisation is performed according to a set of rules and regulations, which started with Bertin's 'Visual variables' in 1967. Bertin (1967) identified 7 different variables to project information onto a map in an understandable way for the reader. These 7 variables are position (location), size, shape, value, hue, orientation, and texture (grain). Scholars agreed on the ideas of Bertin and added visual variables to further complete the list. Morrison (1974) added the variables of saturation and arrangement. MacEachren (1995) further expanded the list of visual variables with crispness (fuzziness), resolution, and transparency (fog), which were now possible due to technological improvements.

Visual variables and symbology are related, as visual variables are ways to modify a symbol so that it holds certain information. Symbols can therefore be seen as the words on a map (Kraak, Roth, Kagawa, & Le Sours, 2021). Symbols are used so that information can be more easily interpreted than when written out in words. Not every visual variable fits every symbol perfectly. For example, figure 4.1 does not include 'Resolution' as it is not meant for points, but for boundaries and images specifically (MacEachren et al., 2012). The coarseness of the resolution is used as an indicator for uncertainty, a coarser resolution would indicate a higher uncertainty (Kinkeldey, MacEachren, & Schiewe, 2014). Moreover, not every visual variable is suitable for each type of information. Some visual variables imply an order in the information (i.e., size, colour value), while other symbols do not indicate any order in the information (i.e., colour hue or shape) (Kraak et al., 2021). It is therefore important to consider the type of symbol and information used for visualisation.

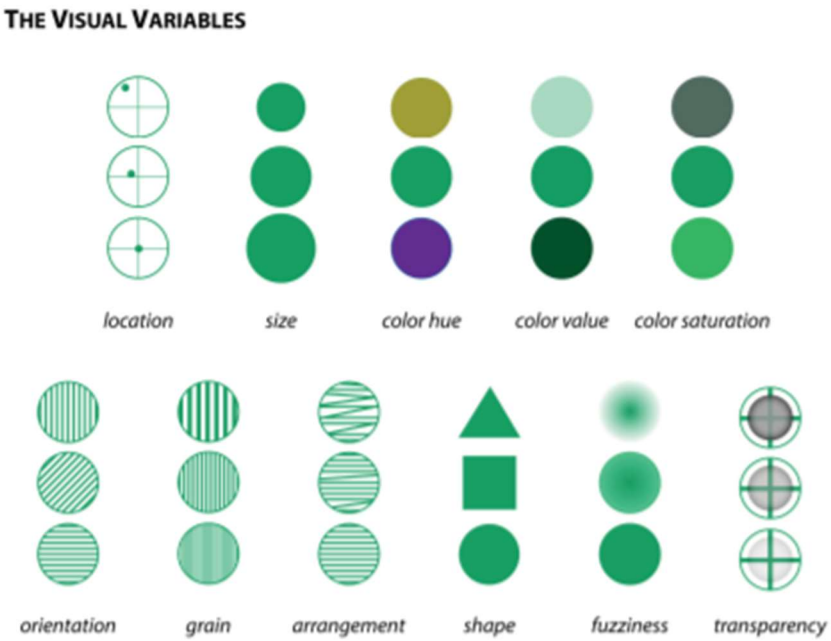


Figure 4.1: The visual variables for point symbology (MacEachren et al., 2012, p. 2497)

4.2 Uncertainty with Boundaries

Different perspectives on where a boundary lays or whether the boundary is internationally recognised as a national administrative boundary result into inconsistency when collecting boundary information from different sources around the world. This inconsistency due to different perspectives has a negative impact on the trustworthiness of the information provided (Kraak et al., 2021). The impact on the trustworthiness can be seen as being related to uncertainty of the

geographical information. Uncertainty is inherent to practically all geographic information (Roth, 2009). This is a form of information uncertainty and therefore it matters what is done with it. As Roth (2009) argues, geoinformation science should focus on how to manage and use uncertainty. This is because uncertainty influences the process of decision-making (MacEachren et al., 2005; Roth, 2009). MacEachren et al. (2005) state that there are different responses to uncertainty, some might want to include the uncertainty in their decision-making process, while others tend to ignore it. They raise the question whether providing data about the uncertainty will lead to different decisions and if so, whether those decisions will be deemed better and more correct (MacEachren et al., 2005). Roth (2009), however, proposes that it is best to give the users or decision-makers a fully informed understanding of the uncertainty involved, so that they can make the best decisions. The method to inform decision-makers and present an understanding of the situation is called uncertainty visualisation.

4.3 Uncertainty Visualisation

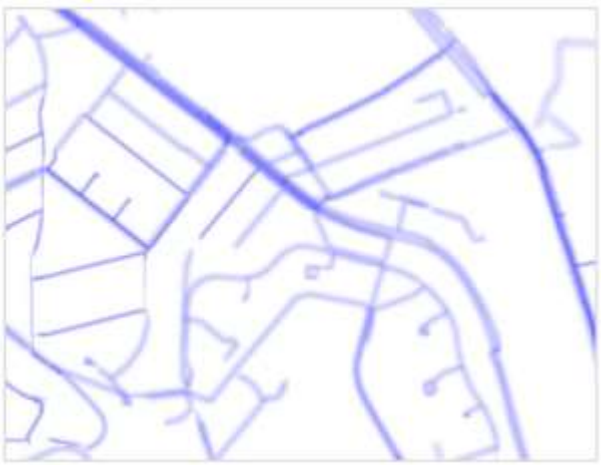
MacEachren (1995) added the last three variables to support the visualisation of data uncertainty specifically. Uncertainty visualisation is suggested by MacEachren et al. (2005) to inform the map reader on what information lies behind the data presented on the map. Information uncertainty is complex and not only limited to the disciplines of geo-information and cartography (MacEachren et al., 2005), for example it is being used in the neurosciences (see: Bonneau et al., 2014; Brecheisen, Platel, Haar Romeny, & Vilanova, 2013; Hermosilla, Brecheisen, Vázquez, & Vilanova, 2012; Siddiqui, Höllt, & Vilanova, 2021). While progress has been made, there is not one comprehensive understanding for what defines a successful uncertainty visualisation (MacEachren et al., 2005). This becomes clear from existing scientific literature, as scholars tend to propose multiple visualisation methods for their specific case of data uncertainty (see: Boukhelifa & Duke, 2009; MacEachren et al., 2005; Roth, 2009; Ruginski et al., 2016). There is not one particular guideline to follow, and neither will there come one, as thus the right visualisation method is dependent on the specific case of data uncertainty.

4.4 Examples of Uncertainty Visualisation

The application of visual variables is dependent on the type of symbology used for the data. MacEachren et al. (2005) and MacEachren et al. (2012) focus their research on point symbology. It is argued that three visual variables are fitting for the purpose of uncertainty visualisation with point symbology: Saturation of the colour, crispness of the symbol edge, and transparency of the symbol. Saturation makes the colour more apparent in the symbol, also referred to as spectral purity of the symbol colour (Kraak et al., 2021). A less apparent colour saturation indicates a higher level of uncertainty. Crispness is sometimes also referred to as fuzziness or blurriness. By making the symbol edge blurrier, it indicates a relatively higher level of uncertainty than symbols with less blurry edges. The idea for transparency is derived from the fog's characteristic of obscuring the view. The symbol becomes more transparent, as if fog covers it. Higher transparency indicates a higher level of uncertainty.

Boukhelifa and Duke (2009) and Ruginski et al. (2016) make use of line symbology in their research. Boukhelifa and Duke (2009) apply uncertainty visualisation for underground pipelines and discuss two methods of uncertainty visualisation: blurriness and 'traffic light' visualisation, see figure 4.2 and figure 4.3. Boukhelifa and Duke (2009) argue, however, that blurriness of the symbol edge is sometimes associated with data quality, rather than data uncertainty. This would make this visualisation variable less suitable for uncertainty visualisation. The 'traffic light' visualisation in figure 4.3 is an application of the colour hue visual variable. Three different colours are used to indicate

different levels of uncertainty. This however causes a problem with how colour hue should be interpreted in the cartography discipline. Kraak et al. (2021) argue that colour hue is an unordered visual variable, which is used for data on a nominal level of measurement. Different levels of uncertainty are categorical, which makes it arguable that colour hue is not an appropriate visual variable for uncertainty visualisation.



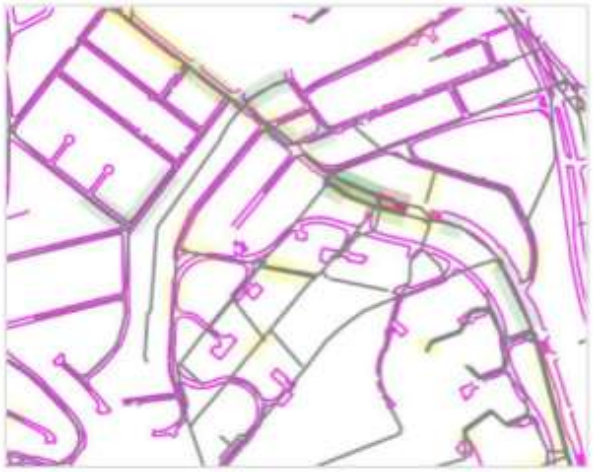


Figure 4.2 (left): Uncertainty visualisation through blurriness (Boukhelifa & Duke, 2009, p. 4054)
Figure 4.3 (right): Uncertainty visualisation trough 'traffic light' visualisation (Boukhelifa & Duke, 2009, p. 4054)

Ruginski et al. (2016) apply uncertainty visualisation for the modelling of a hurricane path. Contrary to the previous examples, Ruginski et al. (2016) do not base their visualisation on the visualisation variables, but a different approach is used. They propose five different methods, see figure 4.4. Though the final route a hurricane takes can be presented by a single line, all the possible paths combined result in an area instead. The 'Ensemble' shows all the possible different paths, a cluster of lines becomes darker, indicating that it is more likely that the hurricane is taking a path in that direction. 'Cone-Centerline' and 'Cone-only' show a simplified version of the ensemble, where the 'Cone-centerline' as well as the 'Centerline-only' also indicate the most likely path. The 'Fuzzy-cone' applies crispness to the cone to indicate the likelihood of the hurricane taking that route.

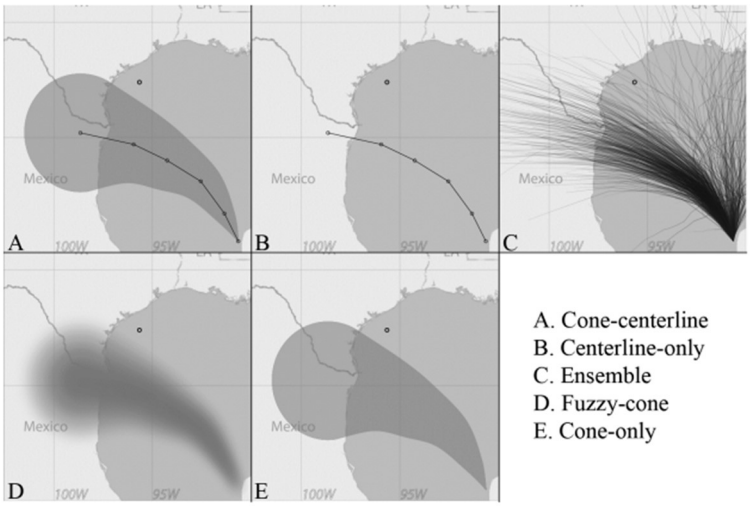


Figure 4.4: Uncertainty visualisation for the path of a hurricane (Ruginski et al., 2016, p. 159)

Glebova (2021) explored the jagged line technique, among other uncertainty visualisation methods, to indicate what respondents believed to be the outline of a university campus. The jagged line technique is used when the exact location of a boundary or polyline is unknown. The jagged line

covers the area of where the boundary or polyline may be. Figure 4.5 shows examples made by Glebova (2021).

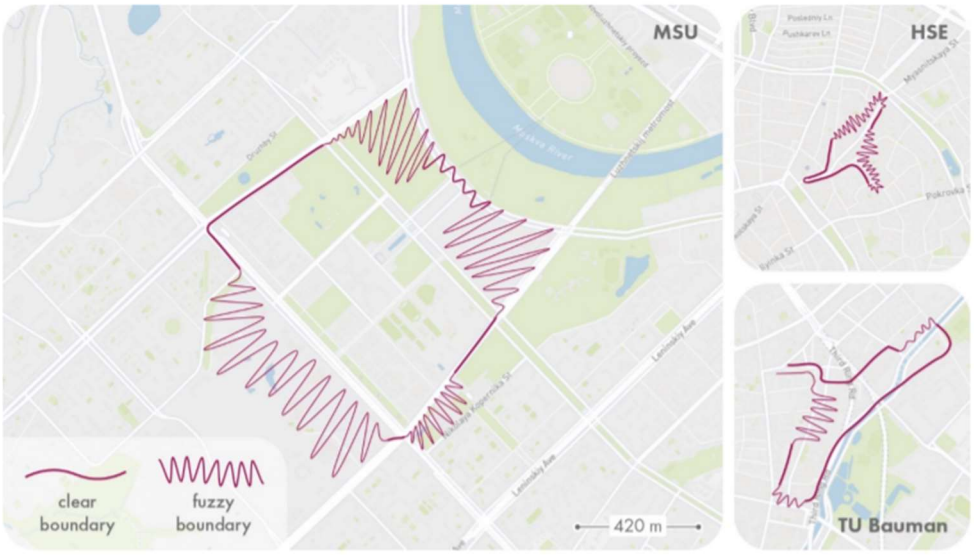


Figure 4.5: Jagged Line Technique for university campus areas (Glebova, 2021, p. 42)

Though Boukhelifa, Bezerianos, Isenberg, and Fekete (2012) state that the best fitting uncertainty visualisation is task dependent, an analysis is performed to determine the usability of different uncertainty visualisation methods. Boukhelifa et al. (2012) evaluate blur (crispness), dashing (arrangement), greyscale (value) and sketchiness. Sketchiness does not refer to any of the previously listed visual variables. It is presented as hand drawn lines compared to computer-generated straight lines, see figure 4.6. Boukhelifa et al. (2012) found that users do not immediately associate sketchiness with the level of uncertainty. However, Boukhelifa et al. (2012) do argue that sketchiness is a viable option for uncertainty visualisation when the users are presented a legend alongside it. For all four methods used in this research, it is advised to make use of levels of uncertainty in an ordinal way, see figure 4.7. None of these methods are deemed efficient for value retrieval by users (Boukhelifa et al., 2012).

Figure 4.6: Sketchiness examples (Boukhelifa et al., 2012, p. 2773)

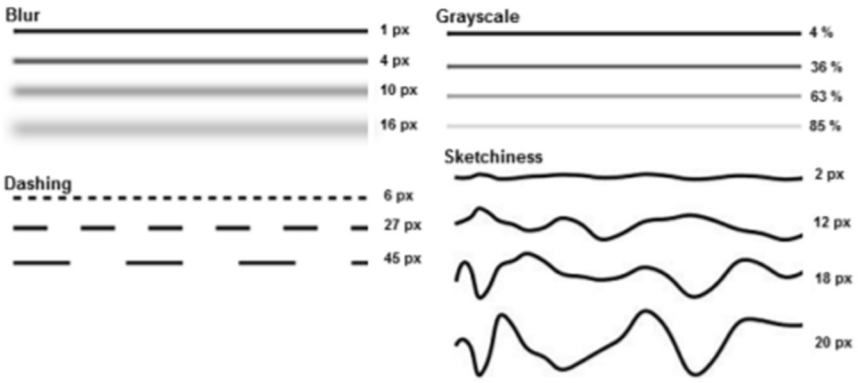


Figure 4.7: Ordinal classes of uncertainty (Boukhelifa et al., 2012, p. 2775)

Zhang (2016) applied uncertainty visualisation to polygon areas. While discussing disputed boundaries, Zhang made the choice to visualise the disputed areas as polygons, rather than visualising the boundaries as polylines. This is done to show two different views on the same area. Figure 4.8 shows China's view on the boundary on the left and India's view on the boundary on the right. The two middle images show the transition from China's view to India's view, directional arrows are used to indicate the transition.

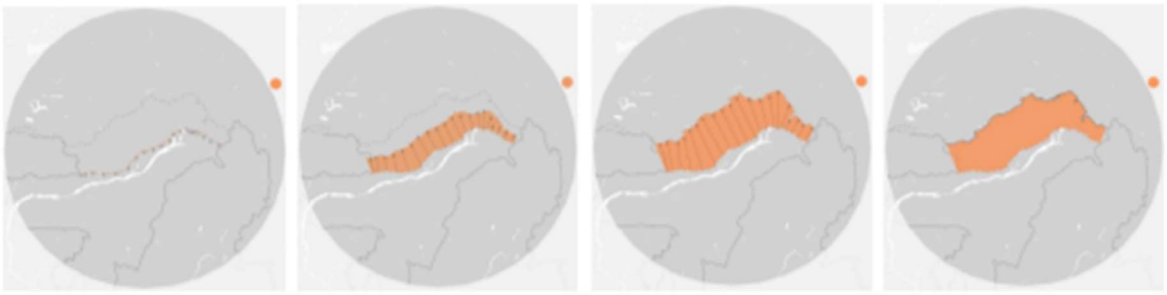


Figure 4.8: Uncertainty visualisation of Arunachal Pradesh (Zhang, 2016, p. 22)

4.5 Visualisation of Disputed Boundaries

In chapter 3, it became clear that most boundaries, including disputed boundaries, are visualised as lines on a map. As Boukhelifa and Duke (2009), Boukhelifa et al. (2012), Glebova (2021), and Ruginski et al. (2016) have shown, there are a number of different uncertainty visualisation options for lines to use. Considering the use of polygons to visualise disputed areas by Zhang (2016), polygons are a viable option for uncertainty visualisation as well. Therefore, both the use of polylines and polygons will be further explored after introducing the case studies.

5. Case Studies

There are numerous boundary disputes found on the world (a full list can be found on Wikipedia, 'List of Territorial Disputes'). Six of these boundary disputes will form the base of the case studies in this research. This paragraph starts with providing a historical background on these boundary disputes and how that caused the dispute to be ongoing as of today. Moreover, the boundary disputes will also be discussed according to the theoretical framework on boundaries, provided in chapter 2. Then, the boundary disputes will be discussed as to how they are currently visualised on atlases and online map environments.

5.1 Abkhazia and South Ossetia

The dispute with on one side Abkhazia and South Ossetia and on the other side Georgia started in late 1980's, when separatist conflicts arose in both Georgian regions. Russia became the biggest supporter of the two regions in the southern Caucasus. Abkhazia and South Ossetia gained a form of autonomy in 1990, becoming de facto states within Georgia (Gerrits & Bader, 2016; Tuathail, 2008). In an attempt to incorporate the regions back under Georgian jurisdiction, Georgia initiated an assault on South Ossetia in August 2008. The Russian Federation started a counterattack to aid South Ossetia. The Russian army beat the Georgian army and pushed them further back than the original de facto boundaries of South Ossetia. Russia remained to occupy those parts of Georgia until October 2008 (Tuathail, 2008). After the Georgian and Russian attacks, known as the five-day war, Russia officially recognised Abkhazia and South Ossetia as independent states (Gerrits & Bader, 2016). Due to similarities with Kosovo's independence and the same time setting, South Ossetia is also being referred to as Russia's Kosovo (Tuathail, 2008). Figure 5.1 shows the locations of Abkhazia and South Ossetia.

The dispute of Abkhazia and South Ossetia with Georgia is of boundary dispute type II: The existence of an administrative boundary is not recognised as the self-proclaimed state is not recognised internationally.

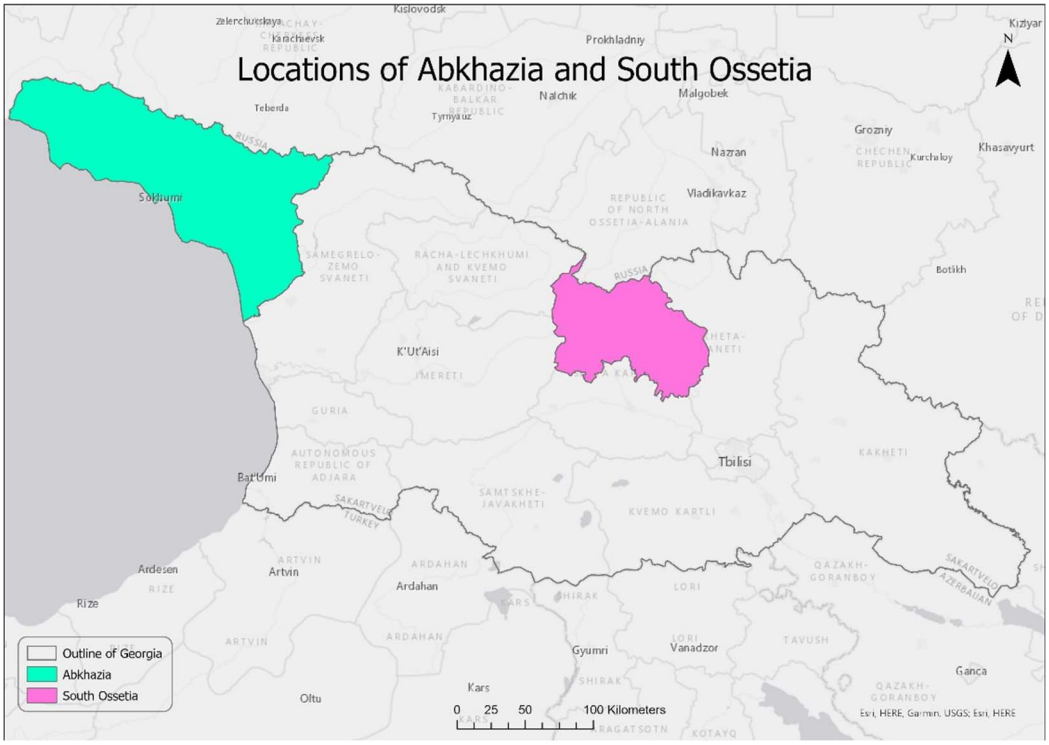


Figure 5.1: Locations of Abkhazia and South Ossetia in Georgia (own work).

5.2 Kosovo

Kosovo is an area of 5000 km² with a population of just over 2 million. 90% of its population is ethnically Albanian. In 1974, Kosovo was made an autonomous province of Serbia under the Yugoslav constitution. Since 1989, Serbia withdrew the autonomy and Yugoslav police forces and the army became more present in the area. Despite the majority of Albanians in the area, the Serbian government views the area as integral part of Serbia: The area of Kosovo was the birthplace of the Serb nation in the 12th century. Meanwhile, the Albanian population did not want to live under Serbian rule and started large-scale protests after the Serbian government initiated a policy to crush the Albian resistance in 1998. NATO ordered air strikes, which put an end to the violence in Kosovo in 1999. Since then, Kosovo had been occupied by NATO and was still seen as a part of Serbia by the neighbouring countries (Anderson, 2000). Kosovo declared independence from Serbia on February 17, 2008. According to Borgen (2010) the declaration of independence caused a 'diplomatic firestorm' (p. 1001). While several countries almost immediately recognised Kosovo, other, mainly European countries stated they had concerns relating to international law. For example, Romania, Cyprus, and Spain opposed against the idea of recognising Kosovo as an independent state. Borgen (2010) theorises that this might have to do with separatist minorities in those countries, such as Hungarians in Transylvania, Turkish Cypriots in Northern Cyprus, and Catalonians in Catalonia. As of today, their independence remains unrecognised by these and other countries. Figure 5.2 shows the area of Kosovo.

The dispute of Kosovo with Serbia is of boundary dispute type II: The existence of an administrative boundary is not recognised as the self-proclaimed state is not recognised internationally.

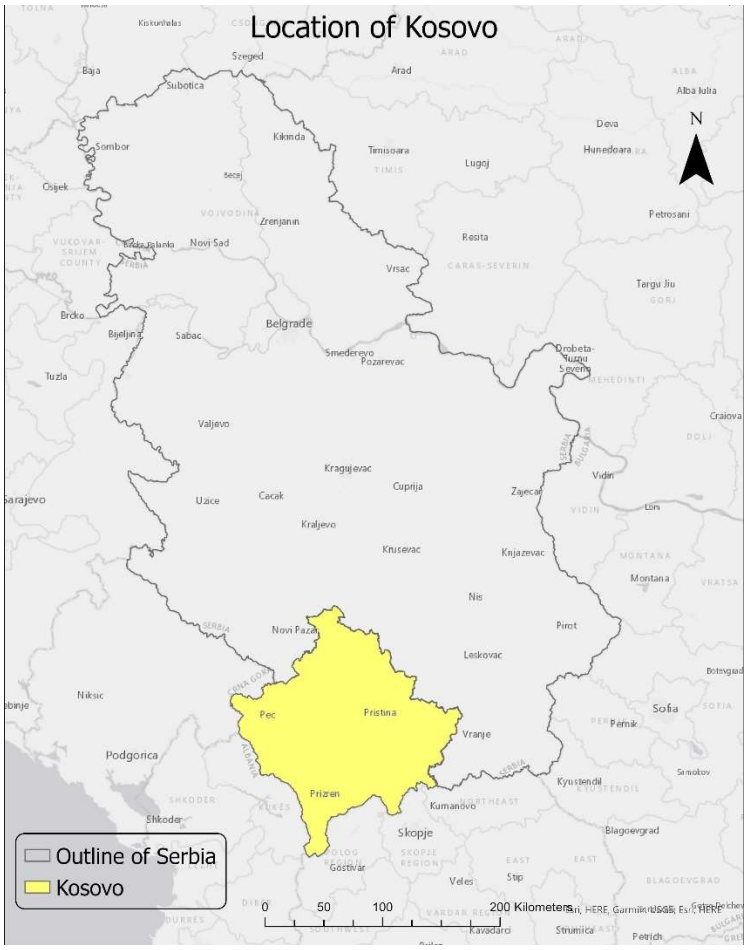


Figure 5.2: Location of Kosovo inside Serbia (own work).

5.3 Western Sahara/Sahrawi Arab Democratic Republic

The dispute of the Western Sahara dates back to the time of the Spanish occupation of the area. In the late 1800's, the Spanish occupied the land what is now referred to as Western Sahara as part of the European colonisation of the African continent. At that time, the area was referred to as the Spanish Sahara. In that same time period, almost all of Morocco had been occupied by the French. In the years after the Second World War, independence wars ignited on the African continent, with the result that a number of African colonies became self-governing, independent countries. As the Europeans did not account for original cultures and historical boundaries, the African colonies were not heterogenous states. As a result, several African countries aspired to expand their territory and thus boundary disputes emerged. Morocco aspired to expand towards what is now known as Western Sahara, Mauritania, and the Tindouf-region of Algeria. The independent states Morocco, Mauritania and Algeria formed an alliance to end the Spanish control of the Spanish Sahara area. These anti-Spanish forces were joined by Polisario (Popular Front for the Liberation of Saguia el-Hamra and Rio de Oro). The intentions of Mauritania and Morocco differed from those of Algeria and Polisario. Algeria supported Polisario to form an independent state. Morocco and Mauritania had conspired to share the area and expand their own countries. Spain supported the idea of Morocco and Mauritania and ended its colonial rule in 1975, splitting the area into a Moroccan and Mauritanian part. Morocco, however, became the sole occupant of the area as Mauritanian forces withdrew due to a military coup in Nouakchott. Morocco built a wall at the Mauritanian border, which had been completed in 1987, and since then claims the whole area of the Western Sahara (Anderson, 1993). As of today, Polisario, still supported by Algeria, continues to (diplomatically) fight for independence to form the Sahrawi Arab Democratic Republic. Morocco considered the area to be its Southern Provinces. Figure 5.3 shows the disputed area of the Western Sahara. The brown area used to be the Spanish Sahara and is now claimed to be part of an independent Western Sahara by Polisario. The yellow line represents the Moroccan Berm, which is the boundary between what is now occupied by Morocco (west) and Polisario (east).

The dispute of Western Sahara with Morocco is of boundary dispute type II: The existence of an administrative boundary is not recognised as the self-proclaimed state is not recognised internationally.

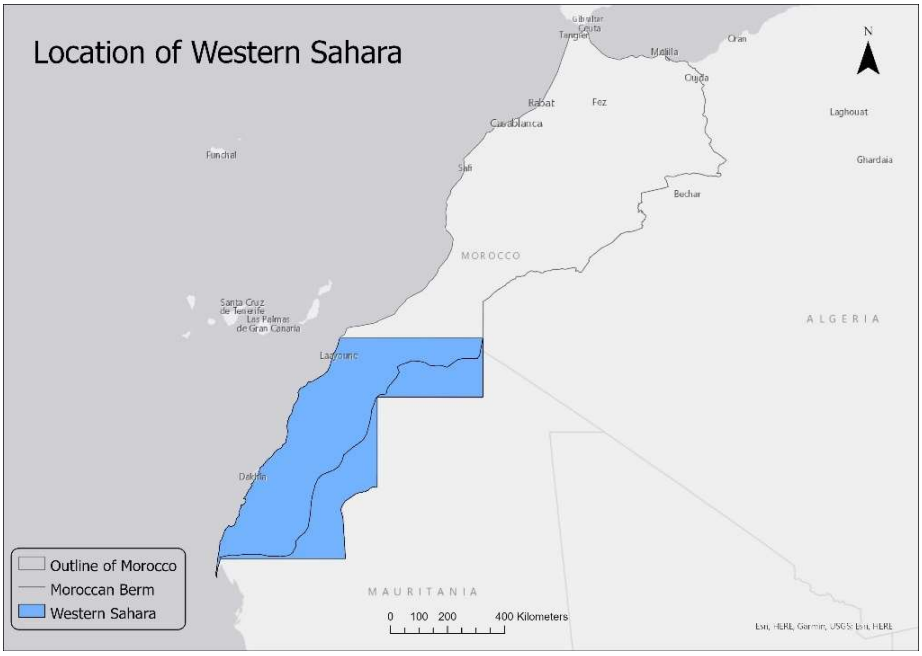


Figure 5.3: Location of Western Sahara and the Moroccan Berm (own work).

5.4 Bir Tawil & Hala’ib Triangle

Similar to the Western Sahara, a boundary dispute between Egypt and Sudan also originates from the time period when it was occupied by European colonisers. The Brits had released two different maps of where the boundary between Egypt and Sudan lay. In 1899, one released map indicates the boundary between Egypt and Sudan to be a straight line, starting at the boundary with Libya all the way to the Red Sea. Egypt holds on to this map as the true visualisation of the boundary between it and Sudan. In 1902, a different map was released by the Brits, which showed the boundary to deviate from its straight appearance when nearing the Red Sea. Sudan holds on to this map as the true visualisation of the boundary between it and Egypt. There are only two stories of how the boundary should be, which essentially created two pieces of land. One piece of land is claimed by both Egypt and Sudan and is known as the Hala’ib Triangle. One piece of land is claimed by neither Egypt or Sudan and is known as Bir Tawil. Both countries prefer the Hala’ib Triangle due to its size, location to the sea, and a population of approximately 27.000 inhabitants. On the other hand, Bir Tawil is described as barren land and is officially unpopulated (Karalekas, 2020). Figure 5.4 shows the areas of Bir Tawil (blue) and Hala’ib Triangle (orange). The southern boundary of Bir Tawil and the northern boundary of Hala’ib Triangle are the boundaries as Sudan claims them to be. The northern boundary of Bir Tawil and the southern boundary of Hala’ib Triangle are the boundaries as Egypt claims them to be.

The dispute between Egypt and Sudan is of boundary dispute type I: The exact location of the boundary between countries is not agreed upon by those countries. The boundary dispute is based on historic/territorial location, as the boundaries were drawn by the previous colonisers of Egypt and Sudan. Neither interpretation of the boundaries are along natural phenomena.

Figure 5.4: Egypt and Sudan, including Bir Tawil and the Hala’ib Triangle (own work).

5.5 Jammu & Kashmir

The dispute at the Jammu & Kashmir region dates back to the British occupation of India, Pakistan, and Bangladesh, historically known as British India. When the British ended their occupation, the Maharajah of each region was given a choice: joining the Hindu Congress Party into forming India or joining the Muslim League into forming Pakistan. Despite 77% of Jammu & Kashmir being Muslim, the Maharajah of the region could not make a decision on which side to join. The British therefore decided that the region became part of India in 1947. Pakistan was convinced that Jammu & Kashmir should be part of Pakistan because of its Muslim majority. Therefore, after the countries were formed, Pakistan invaded the region, which started the conflict. A ceasefire was initiated in 1949, following a line of control that functioned as a de facto boundary between Indian controlled areas and Pakistani controlled areas. Following this, Pakistan signed a deal with China in 1962. This gave China control over a part of Jammu & Kashmir, known as the Karakorum Range, that Pakistan occupied since its invasion. This started a conflict between India and China, as well as reigniting the conflict between India and Pakistan. The latter became partially resolved with the establishment of a new line of control in 1972 (Anderson, 2000). As of today, this line of control still stands. However, not all is resolved, as new conflicts still occasionally arise in this disputed area (Goldman, 2020, June 17). Not only is Jammu & Kashmir disputed in this area. The adjacent Aksai Chin region, de facto administered by China, is also claimed by Indian to be theirs. Figure 5.5 shows the boundaries as each involved state claims them to be. Interrupted lines are used to show overlap between the claimed boundaries. It should be noted that Pakistan and China do not have a dispute. This means that China and Pakistan agree on both claimed boundaries. The Karakorum Range is the area northwest of Aksai Chin, where Pakistan (green) and China (red) deviate from India (blue).

The dispute between India and Pakistan & China is of boundary dispute type I: The exact location of the boundary between countries is not agreed upon by those countries. The boundaries here have multiple natures. The boundary between India and China is based on the Himalayan Mountain ridge. The boundary with India and Pakistan dates back to when Maharajahs controlled the provinces under British rule, which was mainly historical.

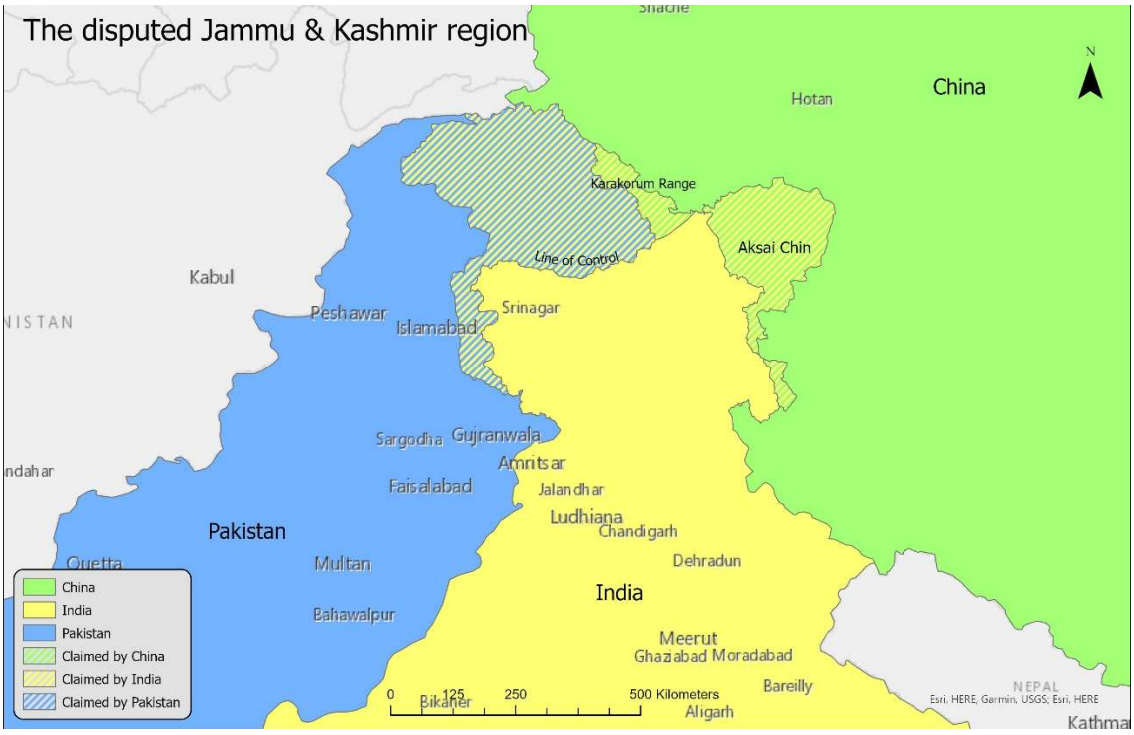


Figure 5.5: All the self-proclaimed boundaries in the Jammu & Kashmir region (own work).

5.6 South China Sea

Other than the previous five cases, the boundary dispute of the South China Sea is related to maritime zones and islands located within those zones, most notably the Spratly Islands (Anderson, 2000) and the Paracel Islands. Disputes on maritime zones are related to the resources located there, such as oil, gas, minerals, and fish. In 1970, it was discovered that the region possibly contained a significant amount of oil and gas, which resulted in a more involvement of countries directly adjacent to the South China Sea (Hong, 2013).

The South China Sea is a boundary dispute that can be described as at least 8 different boundary disputes (Hong, 2013). Brunei, Indonesia, Malaysia, Philippines, Taiwan, Vietnam, and China are all claimants in this dispute. Aside from these nations, the United States and Japan have also involved themselves in this conflict, despite having no claims in the area. Several American oil drilling companies are involved in the area as they are contracted by Asian countries. The US therefore has an interest to maintain peace, so that the oil drilling companies can safely work in the area. Another reason for the involvement of the US is to prevent the loss of freedom of navigation. This reason is mainly because of China, as it claims nearly the complete South China Sea. This would mean that other countries need permission from China to navigate through any part of the sea. This latter reason is also the main reason of Japan to be involved, as it uses the sea for shipping oil and other resources. Moreover, Japan wants to increase its influence in East Asia (Rowan, 2005).

The territorial claims of each directly involved country are shown in figure 5.6. Each territorial claim is indicated with a different colour. China has the largest claim on the South China Sea. This claim is also known as the nine-dash line as it is usually shown in maps with just nine dashes (Rowan, 2005). The green line in figure 5.6 is based on those nine dashes. Figure 5.6 also includes the claim of Taiwan. The recognition of Taiwan as an independent country is disputed, as some countries view it as part of China. However, that is a discussion on its own and is not further explored here. Figure 5.6 includes all involved parties with national boundaries, as defined in paragraph 1.4, who make a claim in the South China Sea and are thus involved with the dispute. Not all claims in the sea are a direct dispute. Indonesia and Malaysia and Indonesia and Vietnam settled their disputed in 1969 and 2003, respectively (Ortolland & Pirat, 2010).

The dispute of the South China Sea is of boundary dispute type I: The exact location of the boundary between countries is not agreed upon by those countries. The nature of the boundary dispute is the EEZ of each country, which is based on the coastline of the countries. However, the nature of the dispute is also economical, due to the various resources located above and under the seabed.

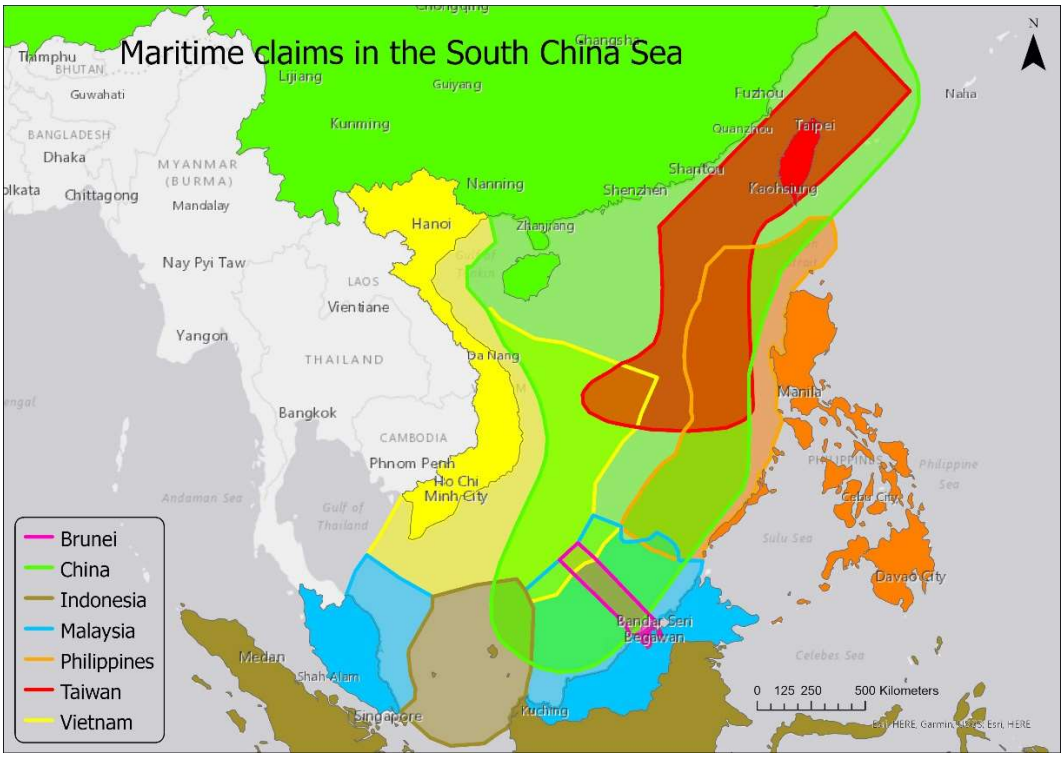


Figure 5.6: Boundaries of the claims in the South China Sea (own work).

5.7 Case studies in the Atlas

The self-proclaimed independencies of Abkhazia, South Ossetia and Kosovo are all relatively recent as they occurred in 2008. Due to the availability of the atlases, these regions are not as much represented as the following other four case studies. As there is more source material on the other case studies, these disputes can be more explored in depth.

Out of 42, only 8 were relevant for Abkhazia and South Ossetia as the maps of these atlases were made after the self-proclaimed independencies of the states. Here, 5 atlases did not show Abkhazia or South Ossetia on world maps or more local maps. 1 atlas indicated the boundaries of the regions as disputed territory boundaries. This means that the regions are still seen as part of Georgia, while they are having a dispute over the exact territory. At last, 2 atlases indicated Abkhazia and South Ossetia as occupied territories. Moreover, Abkhazia was indicated to be an autonomous republic as well. For both areas, the atlases sometimes did not include statistics, see figure 5.7.

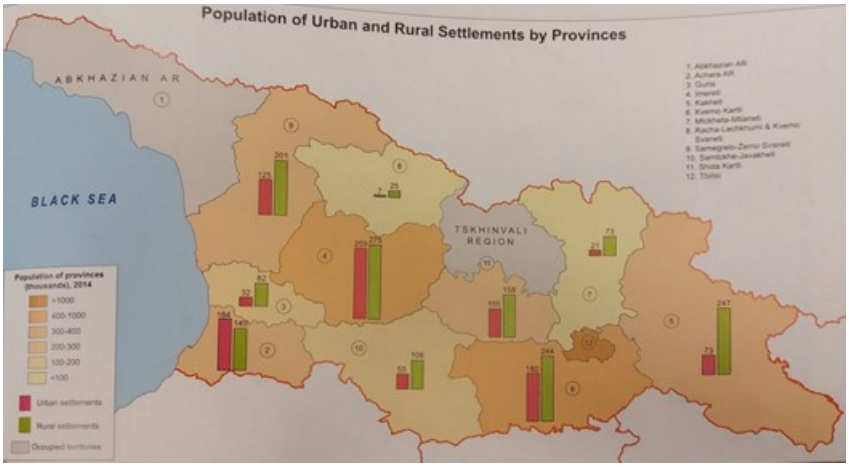


Figure 5.7: Abkhazia and South Ossetia, in National Atlas of Georgia (Bolashvili et al., 2018)

Only 7 atlases were relevant for Kosovo, as one atlas previously relevant only focused on the area of Georgia specifically. Here, 4 atlases showed Kosovo as an independent country on the map. 2 atlases did not show Kosovo on any world or local map, see figure 5.8, and 1 atlas showed the boundary between Kosovo and Serbia as disputed. Contrary to the disputed boundaries of Abkhazia and South Ossetia, the Kosovan boundary was indicated to be a disputed international boundary or alignment unconfirmed. In the terminology of the Times Comprehensive Atlas of the World, this can be seen as a step up. This disputed boundary is not seen as a territorial boundary within a country, but as a boundary between countries.

Figure 5.8: World map of a national atlas not showing boundaries for Kosovo. Despite Panama recognising Kosovo (A'Mula, 2009), it is not included on the world map. (Instituto Geográfico Nacional Tommy Guardia, 2016)

27 atlases analysed were relevant for the area of the Western Sahara. Here, 14 atlases did not show a boundary dispute between the area of Western Sahara and Morocco. 2 of these atlases even referred to the area by its official Arabic name: Sahrawi Arab Democratic Republic. The Western Sahara was shown with national boundaries, as was any other state on the map. Some atlases used colours to fill the area of a country, here it became even more clear that Morocco and Western Sahara were not the same, as different colours for the countries were used. Though there were some cases which showed that while Western Sahara was separate from Morocco, it was not an independent country either (figure 5.9). 9 atlases did show that there was a disputed boundary between Morocco and Western Sahara. One of these atlases, the Times Comprehensive Atlas of the World did change the nature of the disputed boundary. In 2007, it was seen as a disputed boundary between countries, while it was seen as a territorial boundary dispute within a country in 2018 (figure 5.10). Three atlases did not indicate any boundary of the Western Sahara. On these atlases, Morocco and Western Sahara were shown as one state instead. 2 of these atlases were the second and third volume of the Korean National Atlas. The first volume is part of the 14 atlases that did not show any boundary dispute. This, along the example in figure 5.10 again shows the temporality of boundaries.

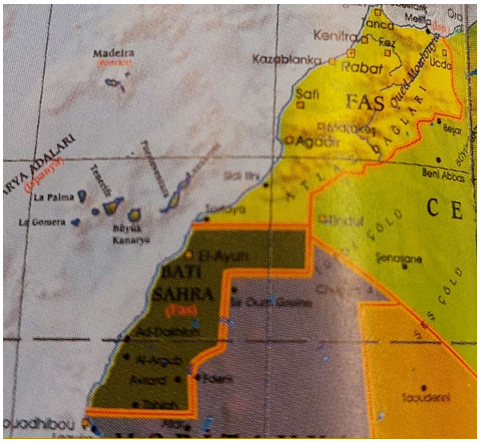


Figure 5.9: Western Sahara in Türkiye Coğrafya Atlası (Atlas Harita, 2004)

Figure 5.10: Boundary of Western Sahara in Times Comprehensive Atlas of the World. Left (Times Atlases, 2007), *right* (Times Atlases, 2018)

31 of the analysed atlases showed the area of the Hala'ib Triangle and Bir Tawil on a map. Only 4 of these atlases showed an objective stance on the dispute. This means, the atlases showed both boundary claims as disputed boundaries and both areas were not filled with a colour, which would otherwise indicate it being part of Sudan or Egypt. 14 atlases mapped the area according to the claim of Egypt, which means that Egypt administers the area of Hala'ib Triangle and Sudan administers Bir Tawil. 13 atlases mapped it the other way around, as Sudan administered Hala'ib Triangle and Egypt administers Bir Tawil. The National Geographic Atlas of the World had multiple versions which mapped the Sudanese claim, while the most recent version of the National Geographic Atlas of the World mapped the Egyptian claim (figure 5.11). This again shows the temporality of boundaries.). It should be noted that while some atlases indicated favouritism for one side, they did use symbology to indicate a disputed boundary. An example is that of the National Atlas of Russia. Though the colours used support the Egyptian claim on the area, the boundary is incomplete, leaving some room for discussion (figure 5.12).

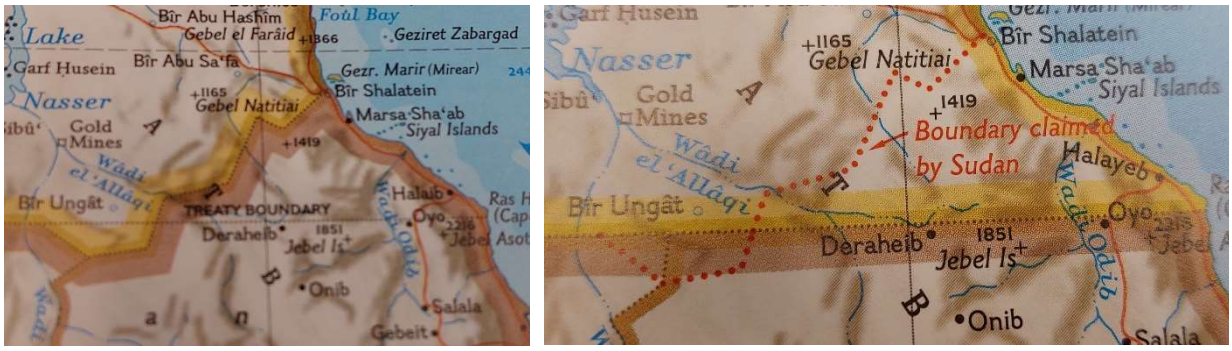
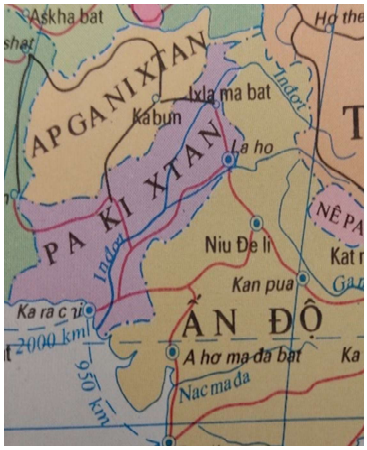


Figure 5.11: Boundary between Sudan and Egypt in the National Geographic Atlas of the World. Left (National Geographic Society, 1999), *right* (National Geographic Society, 2004).

Figure 5.12: Boundary between Sudan and Egypt in the National Atlas of Russia (Kraiukhin, 2008)

31 atlases showed a map of the Jammu & Kashmir region. It becomes clear that out of the six case study regions, this region leads to the most differences between atlases. 13 atlases indicate a boundary between Pakistan and China and include Aksai Chin in Chinese territory (figure 5.13). 1 atlas indicates a boundary between Pakistan and China and includes Aksai Chin in Indian territory. 3 atlases do not indicate a boundary between Pakistan and China and include Aksai Chin in Chinese territory (figure 5.14). 6 atlases do not indicate a boundary between Pakistan and China and include Aksai Chin in Indian territory. 8 atlases do show almost all boundaries to be disputed in the area (figure 5.15). 2 of these do not show disputed boundaries for Aksai Chin, 1 shows it to be Chinese, 1 shows it to be Indian.



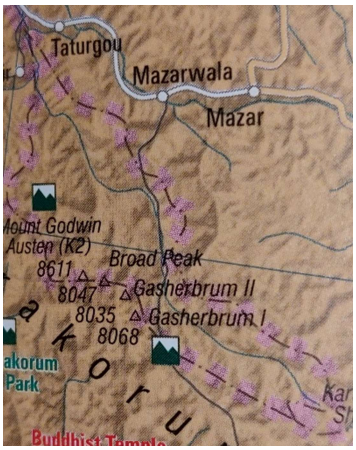


Figure 5.13 (left): The boundaries of India, China and Pakistan near Jammu & Kashmir, in the National Atlas of Korea II (Yi, Lee, Choi, & Chu, 2014)
Figure 5.14 (middle): The boundaries of India, China and Pakistan near Jammu & Kashmir, in the Vietnam National Atlas (*Vietnam National Atlas*, 1996)
Figure 5.15 (right): Part of the disputed Chinese Indian boundary. The northeast boundary is the claim by India, southwest boundary is claim by China (ANWB, 2009)

Only 9 of the analysed atlases are indicating some sort of claim on the South China Sea on a map. All these atlases are rather case specific and mainly focus on the Paracel Islands and Spratly islands. Only 1 atlas shows maritime claims (figure 5.16). Two Chinese atlases have a window on every map focused on the South China Sea, as China claims both the Paracel and the Spratly Islands. The Vietnamese atlas claims the islands to be Vietnamese instead (figure 5.17). Other atlases state that islands are claimed by multiple islands. Moreover, one states that while Vietnam claims the Paracel Islands, China administers it.

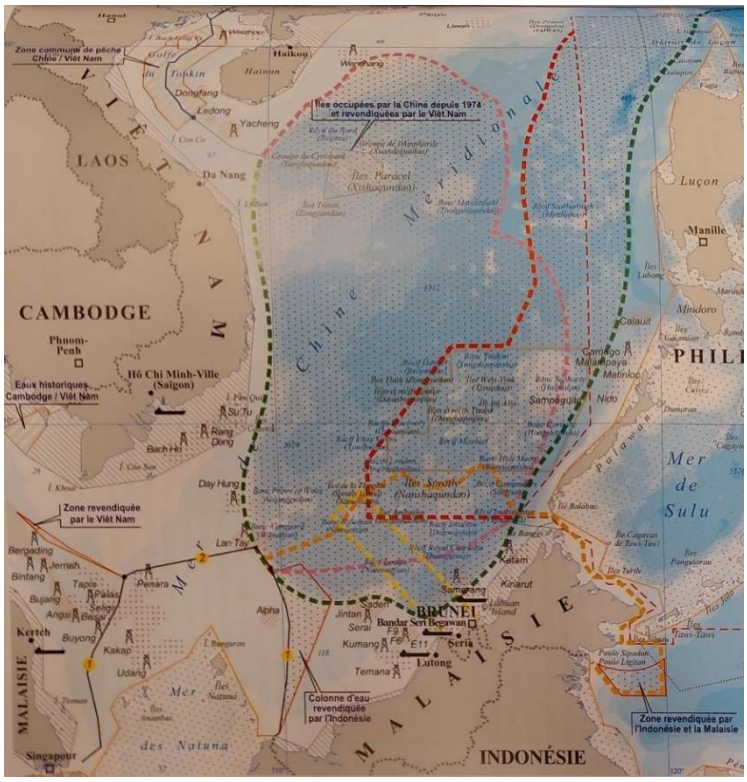


Figure 5.16: Maritime claims in the South China Sea, in Atlas Géopolitique des Espaces Maritimes (Ortolland & Pirat, 2010)

Figure 5.17: Vietnamese claims in the South China Sea, in Vietnam National Atlas (*Vietnam National Atlas*, 1996)

5.8 Case studies in online map environments

13 online map environments were relevant for the case of Abkhazia and South Ossetia as the extent of the environment included the area where these regions are located. Here, 2 online map environments indicated Abkhazia and South Ossetia to be independent states. 9 online map environments did not indicate Abkhazia and South Ossetia on the map (figure 5.18) and 2 online map environments regarded the boundaries between the regions and Georgia as disputed.

Figure 5.18: The Caucasus area, including several separatist regions in Russia and Georgia (Microsoft, 2021)

The same 13 online map environments were relevant for the case of Kosovo. Here, 4 online map environments indicated Kosovo as an independent state (figure 5.19). 6 online map environments did not indicate Kosovo on the map and 3 online map environments did indicate Kosovo on the map but regarded the boundary between it and Serbia as disputed.

Figure 5.19: Snapshot of Yahoo! Japan of the area of Kosovo and Serbia (Yahoo! Japan Corporation, 2021)

Again, 13 online map environments were relevant for the case of the Western Sahara. 7 of these online map environments showed national boundaries for the area, indicating its independence. However, similar as to what was found in atlases, the online map environments do not necessarily show Western Sahara as an independent state. For example, the font used to show the state's name is different than that of surrounding states and Laayoune is not shown as a capital city, but as a regular city on the map.

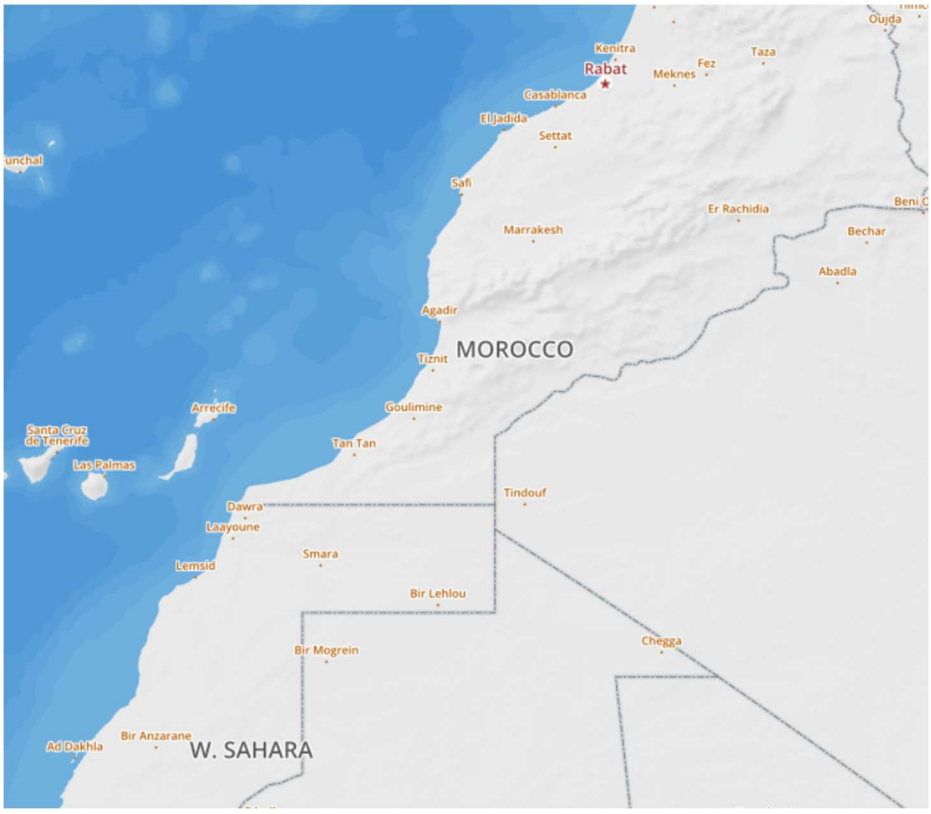


Figure 5.20: Snapshot of Vietbando Maps. Whereas Rabat is indicated as a capital city with a star symbol, Laayoune is not. All boundaries are indicated the same (Vietbando, 2011)

13 of the analysed online map environments showed the areas of Bir Tawil and the Hala'ib Triangle. While the atlases were about equal in terms of favouritism of the Egyptian or Sudanese claim, the online map environments are not. 8 of the online map environments showed the area according to the Egyptian claim. 2 of these showed Hala'ib Triangle as Egyptian and Bir Tawil as no man's land (figure 5.21). 2 of the online map environments showed the area according to the Sudanese claim and 3 online map areas regarded both the Egyptian and Sudanese claims as disputed boundaries.

Figure 5.21: The Egyptian-Sudanese boundary visualised on Longdo Map. Hala'ib Triangle is visualised as part of Egypt. Bir Tawil is surrounded by national boundaries, creating a no man's land. (Longdo Map, 2021)

13 online map environments showed the Jammu & Kashmir region on the map. Here, 5 of these online map environments showed that the boundaries in this region of all three countries are disputed (figure 5.22a). Similar to Bir Tawil in figure 5.21, one online map environment showed Jammu & Kashmir surrounded by national boundaries, indicating it does not belong to any of the countries. Another 5 online map environments regarded Aksai Chin to be Chinese and showed that Pakistan and China have a shared boundary. This means that these online map environments regarded the line of control as the undisputed boundary between India and Pakistan. Only 1 online map environment did not indicate a boundary between Pakistan and China and showed Aksai Chin to be Chinese. 2 online map environments showed the whole Jammu & Kashmir region, including Aksai Chin, to be Indian.

Figure 5.22a: Snapshot of Google Maps NL, showing the disputed Jammu & Kashmir region (Google, 2021)

The disputed boundary shown on figure 5.22a is dependent on the domain from where you explore Google Maps. Figure 5.22a is how Google Maps shows the area to users in the Netherlands, or at least with their location set in the Netherlands. When one changes this location, the boundaries change as well. This is another tactic that is not scale or temporal dependent, but location dependent. It is a solution for showing one specific side of the story, but does not strive objectivity. Figure 5.22b shows how the Jammu & Kashmir region looks like from an Indian perspective on Google Maps. Oddly enough, changing your settings to a Chinese version is not possible. Changing your settings to a Pakistani version gives the same result as figure 5.22a.

Figure 5.22b: Snapshot of Google Maps IN, showing Jammu & Kashmir region to be Indian, including Aksai Chin (Google, 2021)

Only 3 online map environments were relevant in the case of the South China Sea. These were all from states that have a claim on the sea and the islands located within. The Chinese Baidu Maps regarded the whole South China Sea, including Taiwan, as Chinese (figure 5.23). This is interesting, as no other Chinese maritime claims or boundaries are shown. The Vietnamese Vietbando does not show a claim, but states that the Spratly Islands and Paracel Islands are Vietnamese. The Taiwanese NLSC Maps does not show a claim nor is it stated that the islands are Taiwanese. However, when zoomed in, the Spratly Islands and Paracel Island are more detailed. Every reef, atoll or other type of island is named, which is not the case for islands located in other seas. This indicates at least some interest in the islands by Taiwan.

Figure 5.23: Snapshot of Baidu Maps, showing the Chinese claim with 10 dashes (Baidu, 2021)

5.9 Visual Variables

Three different types of national boundaries have been identified in this research. Table 5.1 shows which visual variables have been used to visualise these boundaries. The table also provides information on whether these visual variables had been used in only in paper atlases, only online, or in both instances. For each identified visual variable, one or a few examples are provided on where this had been found. To help understand each visual variable and how it has been used, the table refers to figures listed below that apply these. The area of the Western Sahara and direct surroundings have been used to do so. Figure 5.24 provides a base version of this area, including both claims as how the boundary should be.

Figure 5.24: Area of Western Sahara and neighbouring states

Visual Variables	Accepted Boundaries	Disputed Location	Disputed Recognition	Atlas and/or Online Map	Figure	Source Examples
Size	X	-	-	Atlas	5.25	National Atlas of Georgia Goode's World Atlas
Colour Hue	X	X	X	Atlas & Online	5.26	National Geographic Atlas of the World Yahoo! Japan
Colour/Grey Value	-	-	-	-	5.27	-
Colour Saturation	-	-	-	-	-	-
Orientation	-	-	-	-	-	-
Texture (Hatching)	-	-	X	Atlas	5.31	National Geographic Atlas of the World
Arrangement	-	-	-	-	-	-
Shape	X	X	X	Atlas & Online	5.28	Times Comprehensive Atlas of the World National Geographic Atlas of the World Google Maps Bing Maps Baidu Maps
Fuzziness	-	-	-	-	5.29	-
Transparency	X	-	-	Atlas	5.30	National Geographic Atlas of the World
Resolution	-	-	-	-	-	-

Table 5.1: Overview of visual variables in researched atlases and online map environments

Figure 5.25: Size

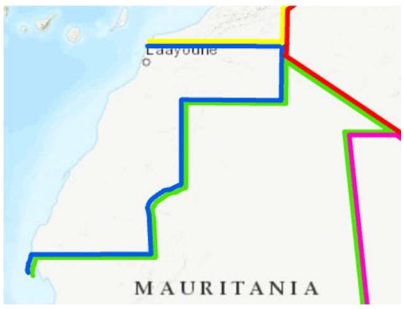


Figure 5.26: Colour Hue

Figure 5.27: Grey Value

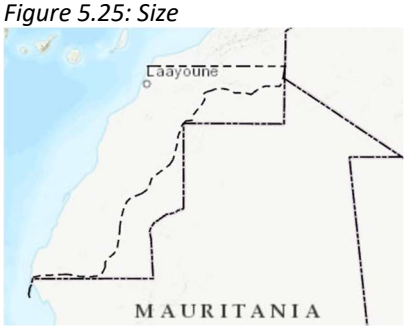


Figure 5.28: Shape

Figure 5.29: Fuzziness

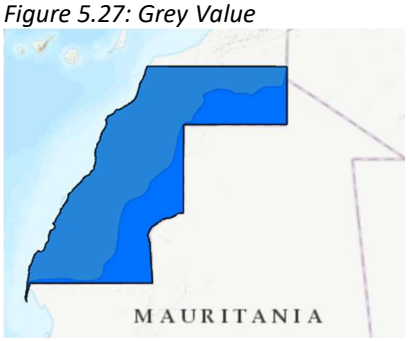


Figure 5.30: Transparency

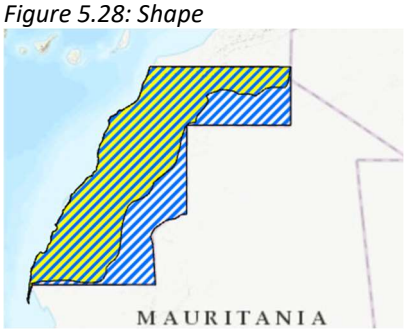


Figure 5.31: Hatching

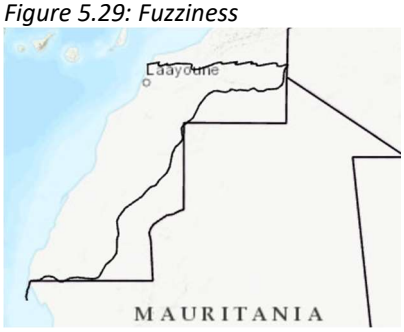


Figure 5.32: Sketchiness

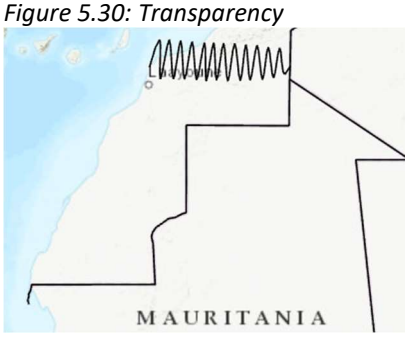


Figure 5.33: Jagged Line

6. Interviews

A final data collection part of this research has been formed by conducting expert interviews. Expert interviews are open or semi-structured interviews purposed to gather expert knowledge on a topic (Audenhove & Donders, 2019). Here, the expert interviews serve to provide feedback on created visualisations for disputed boundaries. The experts have years of experience within the fields of cartography, geospatial information, and disputed boundaries, which makes them suitable to discuss different visualisations. They would know what could work, what should be different, and what would not work at all. A total of three experts have been interviewed. These are 1) a geospatial expert who has an academic understanding of cartography and international experiences due to his involvement with an international cartographic organisation, 2) a school atlas expert, editor-in-chief involved with publishing school atlases for different European countries, and 3) a technical support expert for a geospatial information unit that is actively involved with disputed boundaries and political solutions that come with.

Results from expert interviews are subjective, as the experts are asked about their opinions. Each expert has their own experiences, orientations, beliefs, and points of view. This is something that must be taken in mind when the object of this research is to find objective visualisations. To account for this, the interviewed experts are from different organisations that have a relation to cartography. Moreover, the worldviews of the experts are different as well, as they originate and currently live in different continents on the globe. The inclusion of those differences can be assumed to result into more varying interview answers, thus countervailing the subjectivity of each of the respondents. The interviews have been conducted at the end of January and the first half of February 2022, they had a duration of 60 to 70 minutes.

6.1 Interview pre-processing

The experts are asked because of their cartographic expertise. Therefore, to get the most valuable information out of them, they are presented with examples of visualisations that are applied to the previously introduced case study areas. Before the interviews, it was decided that discussing all 6 case study areas with the visual variables and other techniques discussed in paragraph 5.9 would be too time consuming for an interview. Therefore, choices have been made on which case study areas to include and which visual variables and techniques to discuss.

Bir Tawil and the Hala'ib Triangle are included as the dispute is a bilateral dispute on the location of the boundary. There are only two versions to the story, which makes it a relatively easy dispute to discuss in terms of visualisation methods. The dispute is therefore a good starting point for the interview.

Jammu & Kashmir is included as the dispute is more cartographically complex than Bir Tawil and the Hala'ib Triangle due to being three countries involved. The South China Sea is included as the region is much more complex with 7 countries involved. This also allows to discuss maritime boundaries. Kosovo, Abkhazia, and South Ossetia are combined into one discussion on disputed recognition of the boundaries, as the disputes have similar characteristics. The Western Sahara is not included here as it can be argued that it does not provide a different situation than already discussed with the other case study areas.

Concerning the visual variables and techniques, colour hue and shape alone do not indicate uncertainty, they indicate nominal differences. Therefore, these two variables have been used in combination with other variables and techniques to help differentiate between lines or areas to

increase the understandability of the map. These variables have been used in combination with transparency, hatching and jagged line. Transparency allows the exploration of different levels of uncertainty applied to an area. This is especially relevant when showing a level of uncertainty in the case of boundaries of disputed recognition. As of now, transparency had not been found in atlases for the goal of visualising disputed boundaries. Hatching, on the other hand, had been found in atlases to show disputed areas, especially when an area is claimed by two countries or when a country's administrative rights over an area is contested. Hatching allows to discuss visualising unclaimed areas as well as to discuss why it is suitable and already used for areas claimed my multiple countries. The jagged line is a bit of an odd visualisation technique and is not found in the researched atlases or online map environments. The jagged line has been used for boundaries of disputed location only. The purpose of the jagged line is to indicate an area of where the possible boundary may be.

The experts have been interviewed online using MS Teams. To discuss the visualisations and case study areas, the WebApp Builder of ArcGIS Online has been used. The WebApp Builder allows users of ArcGIS Pro to share their created works online in an interactive webtool. Due to this, the experts could explore the visualisations interactively themselves. This allowed to test different layer settings in the same area. A drawback of ArcGIS Online, however, is that the cartographic options are sparser than in ArcGIS Pro. One expert (school atlas expert) said about this: "ArcGIS isn't a cartographic program, but a GIS program." This especially proved to be a difficulty with the hatching visualisation. A similar visualisation as in figure 5.31, where an area is divided into two colours by the use of hatching, could not be recreated in the WebApp. Other minor issues with specific symbolisation of the lines, i.e., the spacing between hyphens in a line, could not be adjusted. Aside from these issues, the WebApp Builder allowed for high quality data sharing in an interactive environment and was therefore still suitable for the expert interviews.

Bir Tawil and the Hala'ib Triangle have been used to discuss hatching and the jagged line technique. Moreover, the representation of the de facto situation in relation to objectivity has also been discussed. Jammu & Kashmir has been used to discuss transparency, the use of colours and the use of line symbology. South China Sea has been used to discuss a different application of transparency, the objectivity of colours, polyline versus polygon symbology, and interactivity. Kosovo, Abkhazia, and South Ossetia have been used to discuss yet another application of transparency, where it represents the level of uncertainty. See figure 6.1 for all three applications of transparency.

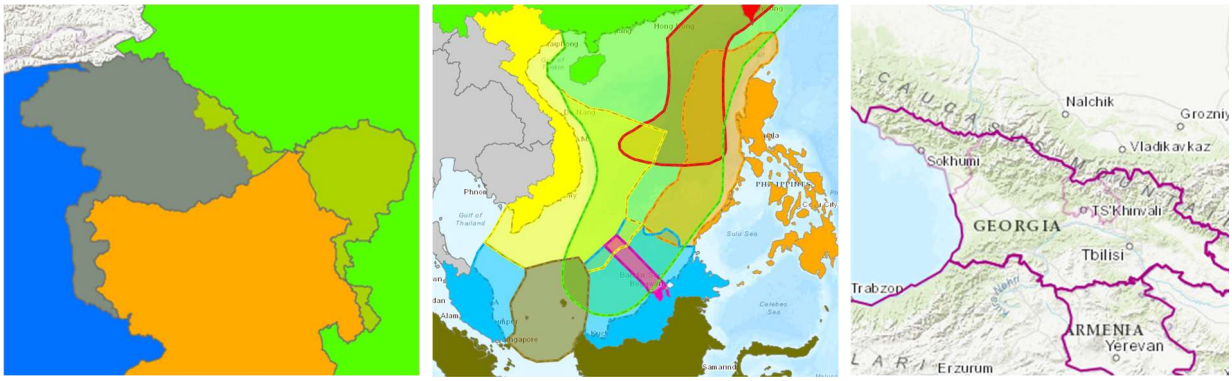


Figure 6.1: Three different applications of transparency. Jammu & Kashmir (left) with 50% transparency on one layer and 0% transparency on the other to create an evenly divided use of colour. South China Sea (middle) with equal transparency to differentiate maritime claims from land mass. Abkhazia and South Ossetia (right) where recognition by number of UN member states is used as attribute to determine the transparency value.

At the start of the interview, the experts were asked to first take a look at the Jammu & Kashmir region on Google Maps. Each respondent looked from his or her own web browser, which showed a representation of the region as in figure 5.22a. This area had been chosen deliberately as the area includes hyphened lines for each claim there is in the area, resulting a bit into a chaotic view. Viewing this area at the start highlights the need for more understandable boundary visualisations. Which then in turn results in the continuation of the interview by the use of created web applications. A list of links to all the discussed web apps can be found in appendix II.

6.2 Interview Results

With the use of the Google Maps view of Jammu & Kashmir, all respondents agreed the need for better and more understandable visualisations. All the lines included in the view are relevant to some extent, but the whole image now becomes unclear. The unclarity is due to a lack of hierarchy, a lack of information about each line, and the absence of a legend. It should be stated that the ultimate goal of Google Maps is not to inform users on disputed boundaries, but when disputed boundaries are included, there should be put more thought into making the area more understandable to its users.

Showing de facto boundaries is an option mostly used for older conflicts. One expert (School atlas expert) mentions that there are so many old conflicts of which the world simply accepted the de facto situation, that it is often chosen as a viable visualisation. Especially for Africa, he argues, you almost have no other choice. Almost every boundary there is somewhat disputed and that would undoubtedly result into a chaotic map. However, when focusing on objectivity, visualising the de facto situation is not reasonable, say the other two experts. Administering or the administration of an area by a country does not define its legal status. It can be stated that it is administered by a country, but that should be done with different symbology to differentiate from legally accepted boundaries, says the geospatial expert. The technical support expert adds that using solid lines and the same colour indication is very confusing. Solid lines are ultimately associated with international boundaries, so they should not be used for de facto boundaries.

The jagged line resulted into the most different answers. One expert (geospatial expert) saw it as noise in a map that would require attention. The fact that it is so different makes it stand out, which indicates that the area would require attention. Another expert (school atlas) saw it as confusing. At this point the line was shown as a solid line, which indicates that it is the actual boundary. The expert argued that this would be very confusing for school children learning about the area. For the technical expert, the jagged line was now indicated by a sequence of hyphens and dots instead of a solid line. From her standpoint, the jagged line does emphasize uncertainty, but also brings in a little bit of confusion. Significant for this visualisation is that outlines as interpreted by Sudan and Egypt are not included. This gives the idea that the location of the boundary could be at any location within the jagged line. It is furthermore argued that this line does indeed draw attention to it, so if it is the goal to get people engaged in the debate on the line, the jagged line would be a successful way to do so.

Despite hatching not being a new visualisation technique, it has been witnessed in a few atlases, it is discussed in the interviews for its viability. Hatching works better when lining two colours next to each other, rather than implementing a thin black hatch over the area. Nevertheless, it helps to indicate that the area is in dispute. The respondents, however, argued that the two areas of Bir Tawil and Hala'ib Triangle are not the same, as Bir Tawil is unclaimed, and the Hala'ib Triangle is claimed by both. Therefore, it would be more suitable to have different visualisations to indicate that difference.

The use of line symbology for the Jammu & Kashmir region was welcomed but was stated to be hard to read on the WebApp. Zooming in on the map did not result into larger lines. Therefore, for the last interview, the line symbology had been enlarged to make it seem more apparent on the map. Overall, the experts were enthusiastic about the line symbology. One respondent (technical support expert) stated that the usage of lines instead of areas includes a more open stance to the dispute. When making claims more apparent by the use of polygons, the claim can be seen as threatening by the opposing party. Using line symbology makes the claim less apparent and thus better fitting for the goal of objectivity. Using an interrupted line is encouraged to emphasise the fact that they are not internationally accepted boundaries. It is important to make sure that the colours are distinguishable and spaced in such a way that every claim is clearly visible, while still holding onto an interrupted line.

A first application of transparency was discussed with the Jammu & Kashmir region. The experts, however, did not find the specific visualisation very fruitful. A transparent blue overlapping a non-transparent orange, resulted into, what experts found, a new colour rather than what can be seen as a combination of the two colours. The transparency worked better for the combination of a transparent green and non-transparent orange as it now looked like a combination of both colours. Therefore, it became clear that the colours need to be carefully chosen on whether they symbolise a combination of two colours, rather than creating a completely different colour. The latter is highly unfavourable, as it does not generate the idea that an area is claimed by two countries, but that the area is a country on its own.

These findings on transparency are contrary to the opinions on how transparency is applied at the South China Sea, where all layers were equally transparent. Here, transparency was actually found beneficial to understanding the information of the map. There are so many different parties involved, that showing just the outlines of the claims was found to be “very confusing” (geospatial expert). The school atlas expert says that the transparent layer helps to understand the visualised situation in an instant. The map can still be understood with just the lines, but it takes much more time to understand what is going on, he argued.

For the area of the South China Sea, it became clear that the area needs colours to help understand the situation. The use of colour is a discussion point itself, as colours are sometimes seen as suggestive or more apparent than others. When asked about this, the experts say that the colour scheme used is fine, as it is beneficial to the understanding of all the claims. The colour red is stated to be drawing the most attention, but when focusing on one of the involved, it is immediately clear what the area of its claim is. Red is just one of many colours so that the seven used colours differentiate enough from one another. However, if the visualisation is meant to start an engagement or debate, it should be wise to think of a strategy on what and how its shown, argued the technical support expert. This can be interpreted as the order of which the layers are drawn and also the choice of colour.

Two experts were also asked to use a query tool. However, the experts were not enthusiastic about it. They found the results overall confusing. The geospatial expert opted for a pan function where information pops up on your screen as you pan over an area. This function should be togglable as it is not always relevant. The school atlas expert provided an example of how allowing people themselves to create figures and maps was not always that successful, as they are no expert in the presentation of those. It should therefore be questioned what the function of interactivity is supposed to achieve: Creating own results or getting a better understanding of the map. For the latter, he argued, the function is irrelevant as the map already provides enough information. Due to these critiques, the interactivity has not been explored during the final interview.

A final form of transparency was discussed with disputed recognition of self-proclaimed independent states, where the boundaries became less apparent due to transparency. However, each of the respondents argued that the map was hard to read, especially for the boundaries of Abkhazia and South Ossetia, which are barely recognised. It was a deliberate choice to make the boundaries not significantly noticeable, the experts, however, found that it had a negative impact on the understandability of the map. Following the critiques of the first two interviews, the thickness of the lines was increased to make the boundaries more noticeable. However, this did not lead to different results. Furthermore, it was suggested to make the disputed countries more noticeable through other means, i.e., using a different colour scheme from red to orange to dark yellow, or highlighting the areas with the use of coloured polygons. It was also advised to make use of just a few classes for clarity purposes.

7. Discussion

This discussion chapter consists of three parts. At first, the results of this research will be discussed and interpreted. Secondly, the process of this research will be discussed and reflected upon. At last, suggestions for further research on this will be discussed and elaborated upon.

7.1 Results Interpretation

Disputed boundaries are the cause of a variety of discussions. This study therefore defined the meaning of a disputed boundary first, but even then, it can be discussed how disputed a boundary is and whether there needs to be a distinction between two different types of disputed boundaries as they have been defined in this research. It may be clear that the two different types of disputed boundaries exist, but it is debatable whether they require a different visualisation to signify that difference. After all, only one example of a different visualisation method had been found in all of the researched atlases and online map environments. In that specific case, hatching was used for a disputed boundary of disputed recognition.

During the analysis of current visualisations of disputed boundaries in atlases and online map environments, it became clear that most of the atlases researched do not have objectivity towards disputed boundaries as their objective. Only 4 out of 31 relevant atlases were observed to be fully objective towards the boundary dispute between Egypt and Sudan concerning the Hala'ib Triangle and Bir Tawil. This raises the question of what the true purpose of an atlas is. The interviewed experts explained that atlases are not just to inform people on how the world looks like generally, but that atlases are a tool to project how the world looks like from a certain perspective. That perspective is mostly defined by nationalism and political agreements. Reflecting back on the case of Hala'ib Triangle and Bir Tawil, it can be assumed that political ties to either Sudan or Egypt influenced how (national) atlases visualised Hala'ib Triangle to be either Sudanese or Egyptian. This argument can be backed up by the fact that the school atlas expert stated that the publishing of school atlases in the Netherlands, France and Sweden all have been influenced by the political stance of the country, the Ministry of Foreign Affairs, and or a strongly present lobby group. This shows that striving towards objectivity, as it is the goal of this research, is hindered by what stakeholders want to see. Nevertheless, as there are a few atlases who have visualised the disputed area as fully objective, there is explorable potential.

One of the purposes of the analysis of current atlases and online map environments was to find what visualisation variables and other techniques work for the visualisation of both accepted and disputed boundaries. The chosen visualisation variables and techniques applied inform readers and users on the area and its (disputed) boundaries. They inherently bring up certain associations or are beneficial in informative terms from which lessons can be drawn. The first item was the line symbology, the different types of shapes of the line and spacing within the line are popular methods to indicate line hierarchy. A solid or thinly spaced line was used as an accepted boundary, a more widely spaced line was used as a disputed boundary. This was also backed up by each of the respondents, who indicated that disputed boundary should most definitely use interrupted lines to distinguish them from the solid accepted lines. A second item was the use of colour hue. Though none of the online map environments used colours for the countries, it has been used by atlases more frequently. Colours are easily recognisable and distinguishable to a certain extent, which helps readers and users to understand a map in a one-eye-view, something indicated to be very important when it comes to map readability according to the school atlas expert. A third and final item was the hatching. Though it had only be found in one atlas, the school atlas expert explained that it was more prevalent in recent atlas versions. When two countries claim an area, the colours of those two countries can be

visualised adjacent through diagonal lines, creating a hatched area. The hatching is only applied when just two countries have an overlapping claim and thus disputed boundary. During the interviews it became also clear that a neutral hatch, black diagonal lines over an area, works well indicating something is up with the area. This worked to signify that Bir Tawil was unclaimed, for example. A problem arises, however, when more than two countries have a dispute over an area.

Methods of uncertainty visualisation have been explored to be able to determine whether those methods can objectively and understandably visualise disputed boundaries and areas. The first uncertainty visualisation method was the jagged line technique. Though received with mixed reactions, the jagged line technique was deemed a possible option when combined with a line symbology different than that of the accepted boundaries. However, the method is rather new, or even unorthodox as described by Glebova (2021). It is therefore recommended to perform further testing with non-cartographic experts, which is further described in paragraph 7.3. A second uncertainty visualisation method was transparency, which had been explored in three different variations. The only effective application, according to the experts, was when transparency was used to visualise overlapping maritime claims of all parties involved in the South China Sea dispute. It still created a chaotic map, but that was due to the fact that seven parties are involved with overlapping maritime claims. The visualisation helped bring some clarity into the overall chaotic situation. The transparency when applied to Jammu & Kashmir did not work, as the visualisation resulted into colours that can be perceived as unrelated to the already present colours. Similar to the jagged line, this could be tested further, but the choice of colours has to be well-made, so that the colours can still be seen as related to the claiming countries. The last option of transparency, applied with the disputed recognition, was deemed illegible due to the small size of the boundaries. Other viable options to visualise these boundaries are left unexplored, though experts advised to make use of colour hue and polygons to make boundaries stand out more. A final must for the disputed recognition is to use a predefined classification with a maximum of 3 to 4 classes, based on figure 4.7 and (Boukhelifa et al., 2012) to improve the readability of the map.

A final remark to the goal of objectivity came from the technical support expert. That is, if one's goal is to start the debate between certain parties that are involved with disputed boundaries, polylines are considered best for this role. Not that polygons are subjective in nature, but they are perceived as more striking on a map. This in turn is perceived as threatening and could hinder the process of negotiating an accepted boundary.

7.2 Process Reflection

A few processes of this research have been influenced as they are dependent on certain variables. It is important to note these to create awareness on what may have influenced the overall outcomes of this research. These are not shortcomings by definition. The first is the availability of atlases and online map environments and how they have been used. The analysed atlases come from the personal collection of the author and the available atlases in the Utrecht University Library map collection. Most of the available atlases were national atlases, that showed only a few maps on the world in a global view. In those maps, there was no space for visualising complex boundary disputes and subjective choices had been made. Nevertheless, there were still global and school atlases available, but it would have potentially strengthened this research were there more to view. Especially when it comes to the most recent versions of atlases. This could be seen when analysing Kosovo, Abkhazia, and South Ossetia in the atlases, as only a few atlases were of the time frame in which these self-proclaimed independent states were already internationally recognised to some extent. The available web map environments were relevant as the goal of this research was also to create a webapp to interview experts. However, the global web map environments used do not focus

on disputed boundaries specifically. This could especially be seen when changing scale, as the boundaries changed depending on which scale one looks at them. That did however provide food for thought on what can be done better with online web map environments. Another process that has been influenced is the creation of the WebApp for the interviews. Though the tools provide some cartographic options, they did not provide every option that was planned to do. As the school atlas expert stated, the used program of ArcGIS is not designed for cartographic purposes, but for GIS analyses and such, which explains why certain tools were unavailable in the Online ArcGIS environment. A final process influenced by variables is the interviews, as it is arguable that selecting specific experts for the interviews is subjective. However, here it can definitely be seen as a strength of this research. As the experts come from such different backgrounds and parts of the worlds, they have entirely different views on cartography. Their interviews proved to be insightful towards possible visualisations of disputed boundaries. Without those, this research would not be as strong.

7.3 Further research suggestions

Following this research, methods of visualising disputed boundaries as objective as possible have been researched, explored, and discussed. However, to further verify how well they suit the aspect of understandability, further testing needs to be done. Experts may have given their opinions, but it is important to include opinions on the functionality of the visualisation methods by non-experts. One expert tried to include a bit of insight on how school atlas users would interpret certain visualisations, but it would be advised to further explore this through usability testing. In the end, atlases, maps, and online map environments are meant for everyone to use, not just people with experience on cartography. Usability testing is meant to improve the ease-of-use of a product by having users test the product. During usability testing, the testers are asked to perform certain tasks, during which their behaviour and duration of the task is measured (Lewis, 2006). Applying this to the visualisation methods, testers can be asked to interpret maps of certain regions where disputed boundaries are located. They can be asked to mark what exactly on the map is disputed and by whom. This becomes especially relevant when more than two countries are involved, as they may not claim all the area. Furthermore, the testers can be asked whether they understand the meaning of all the visualisations that are shown, such as hatching, jagged line, transparency. Time measurement is also important, as it can show that testers take a longer time interpretating a certain map as the visualisation makes it much less understandable. That would then indicate that the particular visualisation method used is not easy to use.

8. Conclusion

This research had the goal of providing a framework and insights on how to visualise disputed boundaries as objective as possible through uncertainty visualisation methods. To come to such a goal, several processes had been undergone. At first, a theoretical framework on boundaries had been formed (SQ1). Secondly, an analysis of current disputed boundaries in atlases and online map environments had been performed (SQ2). Thirdly, uncertainty visualisation methods had been explored and assessed to determine whether they would fit the task of visualising disputed boundaries (SQ3). Fourthly, a framework for uncertainty visualisation has been formulated and realised in an online webapp based on the case study areas. This has then been evaluated through expert interviews (SQ4). These processes have led to a final answer on this research' main question: *"How can geopolitically disputed boundaries be visualised as* objective as possible on a map?"

Boundary disputes appear all across the globe and are not just limited to (inter)national boundaries. These disputes have varying natures, therefore a distinction has been made during the forming of the theoretical framework in figure 2.1: Boundaries can be disputed based on their location (type I) or boundaries can be disputed based on their recognition (type II). Type I is mostly related to boundaries defined by colonisers, which also shows in the case study areas. Other explanations for type I disputes can be the changing course of rivers or the location of valuable resources, i.e., in the South China Sea. Type II is related to separatist movements and freedom fighters that feel oppressed under the current regime and would like to govern their own independent country. Other countries however, especially the country where the separatist movement is located, do not always recognise the independence of it. While these boundary disputes are significantly different, they are rarely marked differently in atlases and online map environments. Only specific examples can be mentioned, such as the UN Buffer Zone on Cyprus or the Line of Control in Jammu & Kashmir.

Most of the researched atlases and online map environments are subjective in their nature and fail to show an overall objective world view. If disputed boundaries are visualised, the most common visualisation is the use of interrupted lines or lines with more spacing than the lines for accepted boundaries have. Especially web map environments refrain from using colour, which decreases the readability of the presented world view. For understandability purposes, it is best advised to make use of a combination of both colour hue and polyline shape. Colour hue is used to identify to which country a certain claim line or claimed area belongs. Polyline shape is used to differentiate accepted boundaries from disputed boundaries.

Overall, it can be concluded that visualising disputed boundaries in an objective as possible way is a difficult task. This research has not found a suitable visualisation method for type II disputed boundaries. The proposed method in this research was not deemed sufficient by the cartography experts. However, this research has been more successful with visualising disputed boundaries of the type of disputed location. Based on the uncertainty visualisation methods, transparency and the jagged line technique have been found to be best suitable in terms of objectivity. The proposed different forms of transparency had mixed outcomes, so further research into the best transparency option(s) is undoubtedly needed. Especially using transparency to clarify the maritime claims of all parties directly involved in the South China Sea was found very effective. The jagged line technique was welcomed with caution, as its understandability is not fully determined. As of now, it is still an unexplored technique new to the visualisation on atlases and online map environments. Its viability and understandability should be further tested before definitive conclusions can be drawn on this.

9. Bibliography

"Boundary". (Ed.) (n.d.) Oxford English Dictionary.

A'Mula, S. (2009, January 16). Panama Recognizes Kosovo. *BalkanInsight*. Retrieved from https://balkaninsight.com/2009/01/16/panama-recognizes-kosovo/#:~:text=Panama%20has%20officially%20recognized%20Kosovo,on%20February%2017%20last%20year.

Amupanda, A. P. (2021). Border dispute resolution mechanisms among Southern Africa countries: Case study of Namibia, Angola, and South Africa. *African Journal of Emerging Issues, 3*(7), 1-13. doi:https://ajoeijournals.org/sys/index.php/ajoei/article/view/212

Anderson, E. W. (1993). *An Atlas of World Political Flashpoints*. London, UK: Pinter Reference.

Anderson, E. W. (2000). *Global Geopolitical Flashpoint: An atlas of conflict*. London, UK: The Stationery Office.

Andreone, G. (2015). The Exclusive Economic Zone. In A. O. E. Donald Rothwell, Karen Scott, Tim Stephens (Ed.), *The Oxford Handbook of the Law of the Sea*. Oxford, UK: Oxford University Press.

ANWB. (2009). *Wereld Atlas*. The Hague, NL: ANWB Media.

Atlas Harita. (2004). *Türkiye Coğrafya Atlası*. Istanbul, TR: Atlas Harita.

Audenhove, L. V., & Donders, K. (2019). Talking to people III: Expert interviews and elite interviews. In *The Palgrave handbook of methods for media policy research* (pp. 179-197). Cham, CH: Palgrave Macmillan.

Baidu. (2021). Baidu Map. Retrieved from https://map.baidu.com/

Bernabé-Crespo, M. B., & Peña-Ramos, J. A. (2019). The management of water resources in a disputed border. The case of Gazivoda reservoir (Kosovo). *Fronteiras: Journal of Social, Technological and Environmental Science, 8*(1), 319-340. doi:http://dx.doi.org/10.21664/2238-8869.2019v8i1.p319-340

Bertin, J. (1967). *Semiology of Graphics: Diagrams, Networks, Maps*. Madison, WI, USA: University of Wisconsin Press.

Bolashvili, N., Dittmann, A., King, L., & Neidze, V. (2018). *National Atlas of Georgia*. Stuttgart, DU: Franz Steiner Verlag.

Bonneau, G. P., Hege, H. C., Johnson, C. R., Oliveira, M. M., Potter, K., Rheingans, P., & Schultz, T. (2014). Overview and State-of-the-Art of Uncertainty Visualization | SpringerLink. In C. Hansen, M. Chen, C. R. Johnson, A. Kaufman, & H. Hagen (Eds.), *Scientific Visualization* (pp. 3-27). London, UK: Springer.

Borgen, C. J. (2010). From Kosovo to Catalonia: Separatism and Integration in Europe. *Goettingen Journal of International Law, 2*(3), 997-1033. doi:10.3249/1868-1581-2-3-borgen

Boukhelifa, N., Bezerianos, A., Isenberg, T., & Fekete, J. D. (2012). Evaluating Sketchiness as a Visual Variable for the Depiction of Qualitative Uncertainty. *IEEE Transactions on Visualization and Computer Graphics, 18*(12), 2769-2778. doi:https://doi.org/10.1109/TVCG.2012.220

Boukhelifa, N., & Duke, D. J. (2009). Uncertainty visualization: Why might it fail? *CHI '09 Extended Abstracts on Human Factors in Computing Systems*, 4051-4056. doi:http://dx.doi.org/10.1145/1520340.1520616

Bow, C. J., Waters, N. M., Faris, P. D., Seidel, J. E., Galbraith, P. D., Knudtson, M. L., & Ghali, W. A. (2004). Accuracy of city postal code coordinates as a proxy for location of residence. *International journal of health geographics, 3*(1), 1-9. doi:10.1186/1476-072X-3-5

Brecheisen, R., Platel, B., Haar Romeny, B. M. T., & Vilanova, A. (2013). Illustrative uncertainty visualization of DTI fiber pathways. *The Visual Computer, 29*(4), 297-309. doi:http://doi.org/10.1007/s00371-012-0733-9

Carter, M. R., & Gregorich, E. G. (2007). *Soil sampling and methods of analysis*. Raton, FL, USA: CRC Press.

Caspersen, N. (2008). Separatism and Democracy in the Caucasus. *Survival, 50*(4), 113-136. doi:http://dx.doi.org/10.1080/00396330802329014

Charlier, R. H., Chaineux, M. C. P., & Morcos, S. (2005). Panorama of the History of Coastal Protection. *Journal of Coastal Research, 21*(1), 79-111. doi:10.2112/03561.1

Couper, A. D. (1983). *The Times Atlas of the Oceans*. London, UK: Times Books Limited.

Darques, R. (2016). *Mapping versatile boundaries: understanding the Balkans*. Cham, CH: Springer.

Eva, H. D., De Miranda, E. E., Di Bella, C. M., Gond, V., Huber, O., Sgrenzaroli, M., . . . Hartley, A. (2002). *A vegetation map of South America*. Luxembourg: Office for Official Publications of the European Communities.

Fall, J. J. (2010). Artificial states? On the enduring geographical myth of natural borders. *Political Geography, 29*(3), 140-147. doi:https://doi.org/10.1016/j.polgeo.2010.02.007

Flint, C. (2017). *Introduction to Geopolitics*. Abingdon, UK: Routledge.

Freestone, D., & Schofield, C. (2016). 2016 Maritime Zones Declaration Act: Drawing Lines in the Sea. *The International Journal of Marine and Coastal Law, 31*(1), 732-758. doi:https://doi.org/10.1163/15718085-12341413

Gerrits, A. W., & Bader, M. (2016). Russian patronage over Abkhazia and South Ossetia: implications for conflict resolution. *East European Politics, 32*(3), 297-313. doi:https://doi.org/10.1080/21599165.2016.1166104

Glebova, M. (2021). *Town and Gown: Visualising University Neighbourhoods as Places within the Urban Environment.* (Master). University of Twente, Enschede.

Goldman, R. (2020, June 17). India-China Border Dispute: A Conflict Explained. *The New York Times*. Retrieved from https://www.nytimes.com/2020/06/17/world/asia/india-china-border-clashes.html

Google. (2021). Google Maps. Retrieved from https://www.google.nl/maps/

Green, E. (2012). On the size and shape of African states. *International Studies Quarterly, 56*(2), 229-244. doi:https://doi.org/10.1111/j.1468-2478.2012.00723.x

Haslem, A., Callister, K. E., Avitabile, S. C., Griffioen, P. A., Kelly, L. T., Nimmo, D. G., . . . Clarke, M. F. (2010). A framework for mapping vegetation over broad spatial extents: a technique to aid land management across jurisdictional boundaries. *Landscape and Urban Planning, 97*(4), 296-305. doi:https://doi.org/10.1016/j.landurbplan.2010.07.002

Hensel, P. R., Allison, M. E., & Khanani, A. (2004). The Colonial Legacy and Border Stability: Uti Possidetis and Territorial Claims in the Americas. *International Studies Association meeting, Montreal*. Retrieved from http://www.paulhensel.org/Research/io05.pdf

Hermosilla, P., Brecheisen, R., Vázquez, P. P., & Vilanova, A. (2012). Uncertainty Visualization of Brain Fibers. *CEIG*, 31-40. doi:http://dx.doi.org/10.2312/LocalChapterEvents/CEIG/CEIG12/031-040

Hong, Z. (2013). The South China sea dispute and China-ASEAN relations. *Asian Affairs, 44*(1), 27-43. doi:https://doi.org/10.1080/03068374.2012.760785

IBRU. (n.d.). River Boundaries database. Retrieved from https://www.durham.ac.uk/research/institutes-and-centres/ibru-borders-research/maps-and-publications/databases/river-boundaries-database/#d.en.457675

Instituto Geográfico Nacional Tommy Guardia. (2016). *Atlas Nacional de la República de Panama*. Panamá, PA: Instituto Geográfico Nacional Tommy Guardia.

Jackson, T. N. (2004). On the date of the first Russian–Norwegian border treaty. *Acta Borealia, 21*(2), 87-97. doi:https://doi.org/10.1080/08003830410001895

Jenkins, R. B., & Frazier, P. S. (2010). High-resolution remote sensing of upland swamp boundaries and vegetation for baseline mapping and monitoring. *Wetlands, 30*(3), 531-540. doi:https://doi.org/10.1007/s13157-010-0059-1

Karalekas, D. (2020). Navigating Terra Nullius: The Ababda and the Case for Indigenous Land Rights in Bir Tawil. *Global Journal of Economics and Finance, 4*(2), 41-49.

Kerkhoven, E., & Gan, T. Y. (2011). Differences and sensitivities in potential hydrologic impact of climate change to regional-scale Athabasca and Fraser River basins of the leeward and windward sides of the Canadian Rocky Mountains respectively. *Climatic Change, 106*(4), 583-607. doi:https://doi.org/10.1007/s10584-010-9958-7

Kinkeldey, C., MacEachren, A. M., & Schiewe, J. (2014). How to assess visual communication of uncertainty? A systematic review of geospatial uncertainty visualisation user studies. *Cartographic Journal, 51*(4), 372-386. doi:https://doi.org/10.1179/1743277414Y.0000000099

Koenders, A. G., & Reynders, D. (2018). Verdrag tussen het Koninkrijk der Nederlanden en het Koninkrijk België voor de aanpassing [...] Eijsden-Margraten en Maastricht en de Belgische stad Wezet, Amsterdam, 28-11-2016. Retrieved from https://wetten.overheid.nl/BWBV0006650/2018-01-01

Kottek, M., Grieser, J., Beck, C., Rudolf, B., & Rubel, F. (2006). World map of the Köppen-Geiger climate classification updated. *Meteorologische Zeitschrift, 15*(3), 259-263. doi:https://doi.org/10.1127/0941-2948/2006/0130

Kraak, M. J., Roth, R. E., Kagawa, A., & Le Sours, G. (2021). *Mapping for a Sustainable World*. New York, NY, USA: United Nations.

Kraiukhin, A. N. (2008). *National Atlas of Russia*. Moscow, RU: Roskartografiia.

Kumar, A. (2021). A relook at the principle of uti possidetis in the context of the Indo-Nepal border dispute. *Jindal Global Law Review, 21*(1), 95-115. doi:https://doi.org/10.1007/s41020-021-00146-5

Lewis, J. R. (2006). Usability Testing. In G. Salvendy (Ed.), *Handbook of Human Factors and Ergonomics* (pp. 1275-1316). Hoboken, NJ, USA: John Wiley.

Little, A. (2015). The complex temporality of borders: Contingency and normativity. *European Journal of Political Theory, 14*(4), 429-447. doi:http://dx.doi.org/10.1177/1474885115584831

Longdo Map. (2021). Longdo Map. Retrieved from https://map.longdo.com/

MacEachren, A. M. (1995). *How Maps Work: Representation, Visualization and Design*. New York, NY, USA: Guilford Press.

MacEachren, A. M., Robinson, A., Hopper, S., Gardner, S., Murray, R., Gahegan, M., & Hetzler, E. (2005). Visualizing geospatial information uncertainty: What we know and what we need to know. *Cartography and Geographic Information Science, 32*(3), 139-160. doi:https://doi.org/10.1559/1523040054738936

MacEachren, A. M., Roth, R. E., O'Brien, J., Li, B., Swingley, D., & Gahegan, M. (2012). Visual semiotics & uncertainty visualization: An empirical study. . *IEEE Transactions on Visualization and Computer Graphics, 18*(12), 2496-2505. doi:https://doi.org/10.1109/TVCG.2012.279

Marshall, T. (2016). *Prisoners of Geography*. London, UK: Elliott and Thompson Limited.

Martí-Henneberg, J. (2005). The map of Europe: continuity and change in administrative boundaries (1850–2000). *Geopolitics, 10*(4), 791-815. doi:https://doi.org/10.1080/14650040500318589

Michelin. (2021). ViaMichelin. Retrieved from https://www.viamichelin.fr/

Microsoft. (2021). Bing Maps. Retrieved from https://www.bing.com/maps/

Milieu, M. v. I. (2021). Drone no-fly zones. Retrieved from https://data.overheid.nl/dataset/5610-drone-no-fly-zones#metadata

Morrison, J. L. (1974). A Theoretical Framework for Cartographic Generalization with the Emphasis on the Process of Symbolization. *International Yearbook of Cartography, 14*(1), 115–127.

Nag, P. (2003). *National Atlas of India*. Kolkota, IN: Government of India.

National Geographic Society. (1999). *National Geographic Atlas of the World*. Washington D.C., USA: Penguin Random House.

National Geographic Society. (2004). *National Geographic Atlas of the World*. Washington D.C., USA: Penguin Random House.

Noordhoff Atlasproducties. (2012). *De Grote Bosatlas*. Groningen, NL: Noordhoff Uitgevers.

Ortolland, D., & Pirat, J. P. (2010). *Atlas Géopolitique des Espaces Maritimes*. Paris, FR: Editions TECHNIP.

PDOK. (2020). CBS Postcode Statistieken. Retrieved from https://www.pdok.nl/viewer/

PDOK. (2021). BRO-Bodemkaart Nederland. Retrieved from https://www.pdok.nl/viewer/

Popelka, S. J., & Smith, L. C. (2020). Rivers as political borders: a new subnational geospatial dataset. *Water Policy, 22*(3), 293-312. doi:https://doi.org/10.2166/wp.2020.041

Rosentrater, L. D. (2015). Integral GIS. In K. O'Brien & E. Selboe (Eds.), *The Adaptive Challenge of Climate Change*. Cambridge, UK: Cambridge University Press.

Roth, R. E. (2009). A qualitative approach to understanding the role of geographic information uncertainty during decision making. *Cartography and Geographic Information Science, 36*(4), 315-330. doi:https://doi.org/10.1559/152304009789786326

Rowan, J. P. (2005). The US-Japan security alliance, ASEAN, and the South China Sea dispute. *Asian Survey, 45*(3), 414-436. doi:https://doi.org/10.1525/as.2005.45.3.414

Ruginski, I. T., Boone, A. P., Padilla, L. M., Liu, L., Heydari, N., K., S., H., . . . Creem-Regehr, S. H. (2016). Non-expert interpretations of hurricane forecast uncertainty visualizations. *Spatial Cognition & Computation, 16*(2), 154-172. doi:http://dx.doi.org/10.1080/13875868.2015.1137577

Siddiqui, F., Höllt, T., & Vilanova, A. (2021). A Progressive Approach for Uncertainty Visualization in Diffusion Tensor Imaging. *Computer Graphics Forum, 40*(3), 411-422. doi:https://doi.org/10.1111/cgf.14317

Stamatiou, E., & Lacroix, R. N. (2008). *Cultural Heritage Of The Coastal Zone- Urban Planning & Reuse Of The WWii "Atlantic Wall".* Paper presented at the WSEAS International Conference. Proceedings. Mathematics and Computers in Science and Engineering., Heraklion, GR.

Times Atlases. (2007). *The Times Comprehensive Atlas of the World*. London, UK: Times Books.

Times Atlases. (2018). *The Times Comprehensive Atlas of the World*. London, UK: Times Books.

Tuathail, G. Ó. (2008). Russia's Kosovo: a critical geopolitics of the August 2008 war over South Ossetia. *Eurasian Geography and Economics, 49*(6), 670-705. doi:https://doi.org/10.2747/1539-7216.49.6.670

Van der Werf, K., Gilissen, H. K., Kleinhans, M., & Van Rijswick, M. (2020). On dynamic naturalness, static regulation and human influence in the Ems-Dollard estuary. *International Journal of Water Resources Development*. doi:https://doi.org/10.1080/07900627.2020.1826293

Van Houtum, H. (2005). The geopolitics of borders and boundaries. *Geopolitics, 10*(4), 672-679. doi:https://doi.org/10.1080/14650040500318522

Veregin, H. (2005). *Goode's World Atlas*. Chicago, IL, USA: Rand McNally & Company.

Vietbando. (2011). Vietbando. Retrieved from http://maps.vietbando.com/maps/

Vietnam National Atlas. (1996). Hanoi, VN: VN Publishing Council of National Atlas.

Voženílek, V., Morkesová, P., & Vondráková, A. (2014). Cognitive aspects of map symbology in the world school atlases. *Procedia-Social and Behavioral Sciences, 112*(1), 1121-1136. doi:https://doi.org/10.1016/j.sbspro.2014.01.1277

Yahoo! Japan Corporation. (2021). Yahoo! Japan. Retrieved from https://map.yahoo.co.jp/?lat=43.33990&lon=18.14811&zoom=5&maptype=basic

Yi, C., Lee, T., Choi, J., & Chu, G. H. (2014). *The National Atlas of Korea II*. Suwon, SK: National Geographic Information Institute NGII) Ministry of Land Infrastructure and Transport.

Zajc, M. (2019). Administrative Legacy and the River Mura Border Dispute between Slovenia and Croatia. *Comparative Southeast European Studies, 67*(3), 369-392. doi:https://doi.org/10.1515/soeu-2019-0027

Zhang, J. (2016). *Borders: visualizing temporal changes in border disputes* (Master's Thesis). University of Illinios, Retrieved from https://www.ideals.illinois.edu/bitstream/handle/2142/90820/ZHANG-THESIS-2016.pdf?sequence=1&isAllowed=n

10. Appendix

10.1 Appendix I: Overview of used atlases and map environments

Symbols inside square brackets indicate the use of the atlases for the case study areas
A = Abkhazia and South Ossetia
K = Kosovo
W = Western Sahara/Sahrawi Arab Democratic Republic
B = Bir Tawil & Hala'ib Triangle
J = Jammu & Kashmir
S = South China Sea

Atlases used:

National Atlases:

-National Economic Atlas, Republic of the Philippines (1973) [S]
-The National Atlas of Japan (1977) [WBJ]
-Atlas of Israel (1985) [B]
-The National Agricultural Atlas of the People's Republic of China (1989) [JS]
-The National Atlas of Japan, revised edition (1990) [WBJ]
-The National Economic Atlas of China (1994) [JS]
-Vietnam National Atlas (1996) [WBJS]
-National Atlas of India (2003) [J]
-Geographical Atlas of Turkey (2004) [WBJ]
-National Atlas of Russia, volume 1 (2004) [WBJ]
-Geographical Atlas of Russia (2005) [-]
-National Atlas of Russia, volume 2 (2007) [WBJ]
-National Atlas of the Republic of Panama (2007) [WBJ]
-National Atlas of Ukraine (2007) [WBJ]
-The National Atlas of Korea I (2007) [WBJ]
-The National Atlas of Korea II (2014) [AKWBJ]
-National Atlas of Russia, volume 3 (2008) [WBJ]
-National Atlas of Russia, volume 4 (2008) [WBJ]
-National Atlas of the Republic of Panama (2016) [AKWBJ]
-The National Atlas of Korea III (2016) [AKWBJ]
-National Atlas of Georgia (2018) [AKWBJ]

World Atlases:

-National Geographic Atlas of the World, 3rd edition (1970) [WBJ]
-National Geographic Atlas of the World, 5th edition (1981) [WBJ]
-National Geographic Atlas of the World, 6th edition (1990) [WBJ]
-Macmillan Centennial Atlas of the World (1997) [WBJ]
-National Geographic Atlas of the World, 7th edition (1999) [WBJ]
-The World Atlas (1999) [WBJ]
-National Geographic Atlas of the World, 8th edition (2004) [WBJ]
-The Times Comprehensive Atlas of the World, 12th edition (2007) [WBJ]
-The Times Comprehensive Atlas of the World, 15th edition (2008) [AKWBJ]
-ANWB Wereldatlas (2009) [AKWBJ]

School Atlases:
-The University Atlas for Australia (1976) [WBJ]
-Atlas Geográfico, Mozambique (1986) [WB]
-Atlas Escolar, Mexico (1987) [WBJ]
-School Atlas, India (2002) [WBJ]
-Goode's World Atlas, USA (2005) [WBJS]
-De Grote Bosatlas, The Netherlands (2012) [AKWBJ]

Other Atlases:
-An Atlas of World Political Flashpoints (1993) [WB]
-Africa Atlas of Our Changing Environment (2008) [WB]
-Atlas de l'Afrique (2009) [WB]
-Atlas Géopolitique des Espaces Maritimes (2010) [S]
-Atlas of Natural Hazards & Risks of Georgia (2012) [A]

Online map environments used:
-Google Maps (American, adjusted to location of user)
-Bing Maps (American)
-Open Street Map (British)
-Baidu Maps (Chinese)
-The Ministry of Foreign Affairs of the Russian Federation (Russian)
-Yandex (Russian)
-Bhuvan (Indian)
-AfriGIS Maps (South African)
-Vietbando (Vietnamese)
-Gezgin (Turkish)
-Longdo Map (Thai)
-Yahoo! Japan (Japanese)
-NLSC Maps (Taiwanese)
-ViaMichelin (French)

Each of the map environments have been relevant for all case studies, except NLSC Maps. This map environment only showed the area of the South China Sea.

10.2 Appendix II: Links to the discussed web app environments

Google Maps location of the Jammu & Kashmir region:
https://www.google.com/maps/@33.5355455,76.6654363,6.36z

Web App of Jammu & Kashmir:
https://uni-utrecht.maps.arcgis.com/apps/webappviewer/index.html?id=65cce15078604b6fb2893fa9eeb8a2d5

Web App of Bir Tawil and the Hala'ib Triangle:
https://uni-utrecht.maps.arcgis.com/apps/webappviewer/index.html?id=37f39f172be347a49c19e6a6714ceed7

Web App of the South China Sea:
https://uni-utrecht.maps.arcgis.com/apps/webappviewer/index.html?id=65fab2f46de540389bb634c04845d85a

Web App of Kosovo, Abkhazia and South Ossetia (disputed recognition):
https://uni-utrecht.maps.arcgis.com/apps/webappviewer/index.html?id=2770ee0439ce40a18a47ff432b7074b3