

GEOVISUAL STORYTELLING OF CLIMATE- INDUCED MIGRATION PATTERNS IN URBAN ENVIRONMENTS

MASTER'S THESIS

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of

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Faculty of Digital and Analytical Sciences

Department of Geoinformatics

and

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With the support of Erasmus+ programme of the European Union. This Master's Thesis has been developed in the framework of the Erasmus Mundus Joint Master Degree (EMJMD) "Copernicus Master in Digital Earth", jointly coordinated by Paris-Lodron University Salzburg, Department of Geoinformatics, Austria together with University of South Brittany, Computer Science Department, France and Palacký University Olomouc, Department of Geoinformatics, Czech Republic.

ANOTATION

This thesis shows how geovisual storytelling can be designed to help urban planners and policymakers understand the patterns behind climate-related human displacement. Two different case studies are compared: slow-onset migration across urban regions in Europe between 2015 and 2024, driven by years of drought stress building up, and rapid-onset displacement in southern Malawi after Tropical Cyclone Freddy hit in 2023. A set of different maps was created using ArcGIS Pro and brought together into one website, combining more than ten different visualization techniques. The platform is meant to describe, not explain: it shows where climate-related displacement happens and how severe it is, without claiming that climate stress directly causes migration

KEYWORDS

Displacement, Cartographic Visualization, Web Cartography, Drought, Tropical Cyclone Freddy

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This thesis has been composed by *Demet Akbaba* for the Erasmus Mundus Joint Master's Degree Program in Copernicus Master in Digital Earth for the academic years 2024/2025 and 2025/2026 at the Department of Geoinformatics, Faculty of Natural Sciences, Paris Lodron University Salzburg, and Department of Geoinformatics, Faculty of Science, Palacký University Olomouc.

Hereby, I declare that this piece of work is entirely my own, the references cited have been acknowledged and the thesis has not been previously submitted to the fulfilment of the higher degree. During its preparation I used generative AI tools for language editing and proofreading only; all research, data processing, spatial analysis, and cartographic outputs are my own, and I take full responsibility for the content of the thesis.

Signature of a student

A handwritten signature in dark ink, appearing to read 'Demet Akbaba', with a stylized, sweeping flourish at the end.

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Demet Akbaba

ASSIGNMENT OF DIPLOMA THESIS

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Theses guidelines

The objective of this thesis is to design a set of maps and non-spatial data visualisations forming a storytelling platform presenting migration trends driven by climate stressors. The student will investigate available data sources, with particular attention to those provided by programmes such as COPERNICUS. Based on this research, the student will design a series of engaging visualisations, including thematic interactive and static maps, spatio-temporal animations, and other data-driven narratives that communicate how climate stressors, such as droughts and floods, affect human migration patterns. Emphasis will be placed on selecting appropriate cartographic and visual analytics methods to integrate both climatic and demographic data into coherent and compelling visual outputs. The platform will aim to clearly communicate both macro-level trends and detailed case studies, making it accessible to a broad audience. The final product is intended for use in education and to support informed decision-making in urban and environmental planning contexts.

The student will attach all created datasets and thesis outputs in digital form. The student will also create a website about the thesis following the rules available on the department's website and a poster about the diploma thesis in A2 format. The student will submit the entire text (text, attachments, poster, outputs, input and output data) in digital form.

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- [1] Lim, Teckwyn & Loke, Vivienne & Solana Mena, Alicia & Pura, Param & Angah, Rizuan & Tan, Ange & Campos-Arceiz, Ahimsa. (2017). Mapping the Distribution of People, Elephants, and Human-Elephant Conflict in Temengor Forest Complex, Peninsular Malaysia. *Malayan Nature Journal*.
- [2] Harissou, Yahou. (2023). Écologie et gestion des grands mammifères de la Réserve de Biosphère du W Niger. 10.13140/RG.2.2.13372.41609.
- [3] Mehta, Abhinav & Shukla, Shital. (2022). GEOSPATIAL APPROACH TO ACHIEVE POTENTIAL WILDLIFE CORRIDOR MAPPING: A REVIEW OF DIFFERENT CASE STUDIES. *Towards Excellence*. 14. 153-166. 10.37867/TE140317.
- [4] Kraak, Menno-Jan & Roth, Robert & Ricker, Britta & Kagawa, Ayako & Sourd, Guillaume. (2020). *Mapping for a Sustainable World*.
- [5] Sitthi, Asamaporn. (2021). Sustainable Tourism: Crowdsourced Data for Natural Scene and Tag Mining. 10.1007/978-3-030-62066-0_8.

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LIST OF ABBREVIATIONS

Abbreviation	Meaning
ARDECO	Annual Regional Database of the European Commission
DTM	Displacement Tracking Matrix (IOM)
ERA5	ECMWF Reanalysis v5 (climate reanalysis dataset)
ESPON	European Spatial Planning Observation Network
FUA	Functional Urban Area
GHSL	Global Human Settlement Layer
HDX	Humanitarian Data Exchange (OCHA)
IOM	International Organization for Migration
JJA	June–July–August (meteorological summer)
JRC	Joint Research Centre (European Commission)
MSLA	Multi-Sectoral Location Assessment (IOM DTM)
NDVI	Normalized Difference Vegetation Index
NUTS	Nomenclature of Territorial Units for Statistics
OCHA	(UN) Office for the Coordination of Humanitarian Affairs

INTRODUCTION

In August 2022, 47% of Europe was under drought warning conditions, with a further 17% in drought alert; the Joint Research Centre judged the event likely the most severe European drought in five centuries (Toreti et al., 2022). The 2018 European drought had already exposed comparable vulnerability, producing a clear north-south climatic dipole across the continent (Buras et al., 2020). These shocks are followed by population relocation, raising a practical question: to where, and under what conditions, do affected populations move? Heat and drought are among the serious factors in maintaining agricultural livelihoods and play a role as a push factor. On the other hand, urban functional areas have the opposite effect. They take on the role of a pull factor, causing migration to be drawn towards cities. However, migration does not have a mechanistic response to stress (de Haas, 2021), so even if a climate shock occurs between the same regions, it can show different mobility outcomes.

Climate-induced displacements do not simply progress slowly and cumulatively. Tropical Cyclone Freddy, which struck southern Malawi in March 2023, caused the displacement of thousands of people from the cities of Blantyre and Mulanje in days. While the concept of drought in Europe can be interpreted as a gradual pressure accumulating over years, the situation with Cyclone Freddy is quite different: an event that unfolds instantaneously, is visible, and has local consequences. The 2018-2022 European drought and Cyclone Freddy in 2023 are, individually, among the most severe climate events to occur in the last few years.

There are two existing studies that illustrate why it is very rare to examine these two displacement rates together: the narrative mapping project Migration Trail and the International Organization for Migration's Climate Mobility Impacts Dashboard (IOM, 2023). Each illuminates part of the picture, yet neither brings a slow-onset and a rapid-onset displacement context together within a single storytelling platform, the space this thesis develops, and which the State of Art examines in full.

This thesis illustrates how geovisual storytelling methods can be designed to communicate the patterns and spatial dynamics of climate-induced displacement to urban planners and policy makers, comparing slow-onset migration in Europe (2015–2024) with rapid-onset displacement in Malawi (2023). The resulting platform is descriptive by design: it visualizes where and how severely these patterns occur, allowing planners to recognize emerging risk and compare how climate stress manifests differently across slow-onset and rapid-onset contexts, without the thesis itself prescribing specific policy interventions.

1 OBJECTIVES

The goal of this diploma thesis, as described in the assignment (PAAV), is: "The objective of this thesis is to design a set of maps and non-spatial data visualisations forming a storytelling platform presenting migration trends driven by climate stressors. The student will examine existing data sources, giving particular priority to the Copernicus program.

To achieve this objective, the thesis is divided into two sections. The first section examines the theories and methods used to create the platform. The second section examines the outputs of the created platform, that is, what it shows. Finally, the theoretical part has three main objectives. The first addresses the four main areas: ways of visualizing spatial changes, climate-induced migration, urban environments, and climate crises. It also focuses on how similar problems are addressed when encountered elsewhere.

The practical part also has three goals. First, it creates 18 map outputs using different mapping techniques. These maps show two different situations: slow migration in urban Europe from 2015 to 2024, and fast displacement in southern Malawi after Cyclone Freddy in 2023. Second, all maps are assembled into a single website-based storytelling platform, organized and explained for urban planners and policymakers, who will also test the platform. Third, it looks at whether and how climate stress and migration patterns match up in each case, but does not claim one causes the other.

Two different study areas were chosen for this purpose. The majority of cities in Europe have become targets in terms of climate stress because climate stress affects many farms in rural areas and causes people to migrate to urban areas. In Malawi, however, the situation is very different; in 2023, people were forced to leave the city due to Cyclone Freddy, which mainly affected the city of Blantyre. This thesis visualizes how people might migrate in different ways due to climate events by evaluating these two different examples simultaneously.

All of these objectives individually align with the structure of the thesis. Chapter 2 essentially reviews the context and theory part of the thesis. The collection and processing of data, as well as how the software is used and the workflow, are discussed in Chapter 3. A detailed examination of the Malawi and European cases and a review of the results are covered in Chapters 4 and 5. Chapter 6 evaluates the outcomes of these two cases together, Chapter 7 discusses the scope of this study within the limits of the literature, and finally, Chapter 8 lists the contributions of this study.

The storytelling platform is designed to help policymakers and urban planners see where the risk of displacement and migration from climate stress, such as drought, is highest. It also lets them compare fast and slow patterns of risk. The platform is meant to describe these patterns, not to prove anything statistically or to guide policy decisions.

2 STATE OF ART

2.1 Urban Environments and Climate Vulnerability

The literature contains numerous definitions of the urban environment that are not universally accepted and vary across disciplines. Generally, three broad approaches stand out: a definition based on fixed administrative boundaries (such as city or municipal boundaries); a morphological definition related to the physical dimension of the dense and built-up area, and its contiguous nature; and a functional, area-based definition that is socially and economically integrated with the urban structure through infrastructure, services, and transportation, regardless of where the administrative boundaries are located.

Urban environments absorb and experience climate-related stress, but the ways in which they do so are not homogeneous. Functional urban areas (FUAs) are defined in the European regional typology. These areas concentrate infrastructure, population, and employment with the city center as a reference point (Dijkstra et al., 2019). The IPCC also points out that cities face higher climate risk mainly because so many people and so much infrastructure are packed into a small area. But this risk isn't spread evenly within a city — it depends on things like how strong local institutions are, how the local economy and society are structured, and how good the infrastructure is (Dodman et al., 2022). This population concentration is what makes these areas attractive, despite being under climate stress: social infrastructure, jobs, and services are much more concentrated around the city than in rural or peripheral areas. In the case of Malawi, the situation is quite different. Blantyre is already a city center, and the impact of Cyclone Freddy on this city center demonstrates how climate shocks can lead to instantaneous, spatially concentrated displacement in urban areas, rather than a gradual distribution..

2.2 Climate-Driven Migration: Definition and Current Occurrence

Climate-driven migration does not have a single, universally accepted definition; multiple definitional approaches coexist in the literature, differing in whether movement must be forced or voluntary, temporary or permanent, and whether climate must be the sole or merely a contributing driver (Cissé et al., 2022). This thesis uses "climate-driven migration" as an umbrella term covering both ends of a severity and timescale spectrum: slow-onset stressors, such as drought, desertification, and long-term temperature increase, which accumulate pressure gradually over years; and rapid-onset stressors, such as cyclones, floods, and wildfires, which can displace large populations within days. Two related but distinct terms are used throughout this thesis: migration refers to movement that may be voluntary or semi-voluntary and is typically studied over longer timeframes (as in the European case), while displacement refers to movement compelled by an acute shock, which may be temporary or permanent (as in the Malawian case). The two terms describe points on the same underlying phenomenon of climate-related human mobility rather than mutually exclusive categories.

The European droughts of 2018 and 2022 illustrate the slow-onset end of this spectrum. The 2018 event was a continent-wide north-south polarization, described as a "warmer drought," where decreasing water availability and high temperatures mutually reinforce each other, and grasslands and cultivated lands are more sensitive than forests (Buras et al., 2020). The 2022 drought model intensified this situation even further. The European Commission's Joint Research Centre found that this was likely the worst drought Europe had seen in the last five hundred years. By August of that year, 47% of Europe was under a drought warning, and 17% was under a more serious drought alert (Toreti et al., 2022). On the other hand, on a somewhat more local and ecological scale, Choler (2023) identified a fairly widespread anomaly in annual vegetation greenery in Alpine ecosystems and documented the cause as relatively reduced snow cover and decreased early summer rainfall.

An extreme event is a strong example of Tropical Cyclone Freddy that affected southern Malawi in March 2023. "Thousands of people have been displaced in a matter of days, especially in places like Blantyre and Mulanje.

The critical point is that the relationship between climate stress and migration is not mechanistic. De Haas (2021) argues that migration depends on both the desire to move and the practical ability to do so, explaining it within the framework of will-ability; interpreting staying put under stress not as a passive failure to migrate, but as a form of action in itself. This means that climate stress can be associated with migration in an uneven way across regions and time, and that it should be expected not to produce a uniform, synchronized response. This expectation should be considered when interpreting the results of this thesis (see Chapter 6, Results).

2.3 Suitable Data Sources

When people study migration caused by climate change, two kinds of data matter most: data about climate and environment stress, and data about migration and displacement. For each of these phenomena, there are quite different sources in terms of usage, the space they cover, and how often they are updated and the effort required.

The main places to find such migration and displacement data are international groups, particularly in the European Union, such as EUROSTAT or ARDECO. These groups are usually in different regions, but they use mostly the same methodology and publish these migration figures regularly. For example, ARDECO is created for a single clear purpose: it takes pre-calculated raw figures and converts them into usable figures (including pre-calculated net migration figures), thus enabling matching between regions. This allows researchers working on this topic to avoid having to perform extra cleaning of migration and immigration figures. Furthermore, ARDECO's executives have provided clear explanations of how their databases work and how they calculate values such as per capita population figures (Baggio et al., 2024).

Regarding post-crisis reporting, humanitarian aid coordinating groups such as the UN Office for the Coordination of Humanitarian Affairs (OCHA) and the International Organization for Migration (IOM) provide highly up-to-date reports, particularly on sudden displacements.

They update these reports as they gain more information on people's movements, updating the data as well, and presenting all of this in a report. This thesis specifically focuses on the IOM's Displacement Tracking Matrix, mobility tracking, flow tracking, recording, and surveys developed for the Malawi case study, and follows their methodology.

For climate and environmental stress data, reanalysis datasets, such as ERA5 (Climate Data Store), combine historical observations with numerical modelling to produce spatially continuous, long-run temperature and weather-variable records suitable for anomaly calculation (Hersbach et al., 2020). Satellite-derived vegetation indices, such as NDVI (Normalized Difference Vegetation Index), obtained via services such as the Copernicus Land Monitoring Service, provide a widely used proxy for vegetation health and drought stress since Tucker's (1979) original formulation linking the red/near-infrared band ratio to green leaf biomass, though the literature cautions against treating any single seasonal time window as universally the strongest indicator; cumulative seasonal water balance and alternative monthly windows can matter as much as a single late-summer snapshot (Buras et al., 2020; Possega et al., 2023). Population and settlement data, needed to interpret both migration and displacement in context, are available from census-based grids, regional statistical agencies, and satellite-derived settlement layers such as the Global Human Settlement Layer (GHSL), whose population, built-up, and degree-of-urbanisation grids are produced through a joint assessment of Earth observation and population survey data (Florczyk et al., 2019).

The sources selected from among these possibilities, and the reasons for selecting these sources, are explained in Chapter 3 (Methodology).

2.4 Methods for Visualisation Dynamics

This thesis focuses on these two facets of visualization theory, while also demonstrating how they complement each other. The first shows the position of visualization in terms of its narrative tool function, and the second demonstrates how the accompanying graphic components of the maps support the data.

Segel and Heer (2010) have a rather sophisticated approach at this point, generally believing that compatible components can create a whole and tell a story, and they have explained how designers can use many types of visual elements, such as journalistic data storytelling and research visualization, to convey and make the visual components understandable to the reader.

At the level of the individual map, Bertin's (1967) theory of visual variables, originally developed through cartographic practice, established the systematic basis for encoding data in graphics through seven variables: position, size, shape, orientation, color (hue), value, and texture, a framework that remains foundational to cartographic design more than fifty years after its original publication.

Several established cartographic techniques exist for representing spatial magnitude, categorical distribution, flow, and temporal change, each suited to different aspects of a migration-related dataset (Slocum et al., 2009). Graduated (proportional) symbol maps represent a quantitative variable through symbol size at point locations; when point locations are derived from population-weighted raster aggregation rather than administrative boundaries, this technique is sometimes referred to informally as a "Wurman dot" map. Choropleth mapping instead shades entire administrative or statistical polygons according to a classified quantitative or ordinal variable, and remains one of the most widely used thematic mapping techniques for regional comparison, though the choice of classification method is a long-standing debate in its own right, since an improper choice can obscure rather than reveal the underlying pattern (Andrienko et al., 2001); the technique can also visually overweight large, sparsely populated areas relative to smaller, densely populated ones. Bivariate mapping extends the choropleth principle by encoding two variables simultaneously. This is most often done through a two-dimensional colour matrix, but the same principle can be carried by other visual variables, for example by combining symbol size with colour, texture, or orientation, or by using bivariate glyphs; whichever encoding is chosen, it allows a reader to identify where two conditions co-occur, at the cost of a more complex legend; Trumbo's (1981) theory of colouring bivariate statistical maps remains the foundational reference for constructing a colour matrix in which both variables, and their joint extremes, remain visually distinguishable. Origin-destination (flow) mapping represents directional movement between paired locations using lines whose thickness or color typically encodes flow volume, making it well suited to migration and displacement data specifically, though flow maps can become visually cluttered at high volumes or high spatial density. Finally, animated or time-series symbol maps extend any of the above static techniques across a temporal sequence, allowing a reader to perceive change over time directly rather than inferring it from a series of separate static maps, a technique that depends on the narrative-visualization principles described above to remain interpretable across many frames.

Cartographic representation of human movement itself has a long history, extending from early computational migration mapping through to contemporary techniques combining flow lines with density or bivariate symbolization (Guo & Zhu, 2014). None of the techniques surveyed above is individually novel; each is well-established within cartographic practice. The main contribution of this thesis is not to present new mapping techniques, but to offer users, on a single platform, specific maps produced with different techniques in two structurally distinct climate-displacement and migration contexts. The different techniques chosen for each map and how they were applied, as well as the steps taken in creating the platform, are explained in Chapter 3 (Methodology).

2.5 Similar Studies and Platforms

Very few existing projects in the research so far actually deal with the topic of this thesis. One of them is the International Organization for Migration's Climate Mobility Impacts Dashboard (IOM, 2023). This dashboard shows population density, economic vulnerability, and exposure to climate hazards, both around the world and at the national level, pointing out which regions are most at risk as warming increases. Rather than focusing on site-specific analysis, it aims to guide policymakers going forward and was presented at COP28. Another example is Toffano and Smets' (2021) "Migration Trail"

analysis, which demonstrates how visualization through interactive maps and storytelling plays a unifying role in narrating human mobility without focusing on a specific climate stressor factor. Finally, Garrison's (2021) master's thesis is almost at the same academic level as this thesis, but without any methodological comparison, it designed storytelling maps aimed at emotional response, thereby measuring whether it changed the reader's attitude toward climate change.

Based on the information obtained from this research, no existing study, aimed at regional planning target audiences, combines a rapidly developing displacement event with a slow-growing migration trend, presenting a comparison using various cartographic techniques and design. This thesis provides research and results aimed at filling this gap.

3 METHODOLOGY

Map design and ArcGIS Pro tools are used throughout this thesis to build one website platform. Chapter 2 (State of Art) looked at five common mapping techniques: graduated symbols, choropleth maps, bivariate maps, origin-destination flow maps, and animated time-series symbols. This thesis picks the first four and uses them the same way in both case studies. Graduated symbols, also called Wurman dots, are used for population. Since the Demographic Heartbeat migration series shows migration data within the boundaries of the urban environment, choropleth maps, the most suitable mapping technique for this situation, are used. Bivariate color schemes are used for the two maps titled Climate Stress, and graduated points are used in the displacement map produced for Malawi to show camp locations and numbers more clearly, and the lines representing flows are also graded.

The fifth technique used to show the change in the Demographic Heart Rate series over time is a swipe tool, but instead of a single moving map, a 10-year map covering the years 2015-2024 is displayed. This allows the user to pause and examine any details as needed. (§4.4).

In addition to the map techniques described, each map also includes a graph appropriately selected and positioned to reflect its theme. For example, each of the ten maps in the Demographic Heartbeat series has a histogram, while the Climate Stress Grid, which compares NDVI and temperature phenomena, is complemented by a scatter plot. The Economic Magnet was chosen because a bar chart was thought to be of interest to users as it shows gains and losses. Finally, Bivariate Susceptibility has a distance scatter chart because the distance of the landslide to the population distribution is examined on the map. Considering all this, a total of more than ten visualization techniques have been applied throughout the thesis.

Throughout the thesis, specific mapping techniques were chosen for each map, these choices were also specifically made for the graphs, and each choice is based on Bertin's (2010) ideas about visual variables. For example, larger symbols were used to show larger population or flow numbers because this approach is fundamental to graded symbol and flow maps. How the layout, colors, and fonts were used to apply this style consistently to each map while also highlighting the differences between them is explained in §3.3.

The designed platform is a website created by presenting 18 completed static maps in a narrative form under 7 headings, each paired with supporting text, visuals, and videos.

This is not a picture board that users try to discover on their own, or a story where they have to follow a specific path, as defined by Segel and Heer (2010), but rather a carefully planned sequence that is left for them to interpret and comprehend. Because a storytelling map sequence can show even spatial patterns much more effectively than a number table or a long written report. The main reason for choosing this idea for the thesis is that when maps are arranged in a planned order and effectively produced with colors and symbols, they can convey the intended message more quickly than any plain text.

All the details and workflow regarding the processing of the data, the designs, and the publication of the website after its completion are also shown in Figure 1.

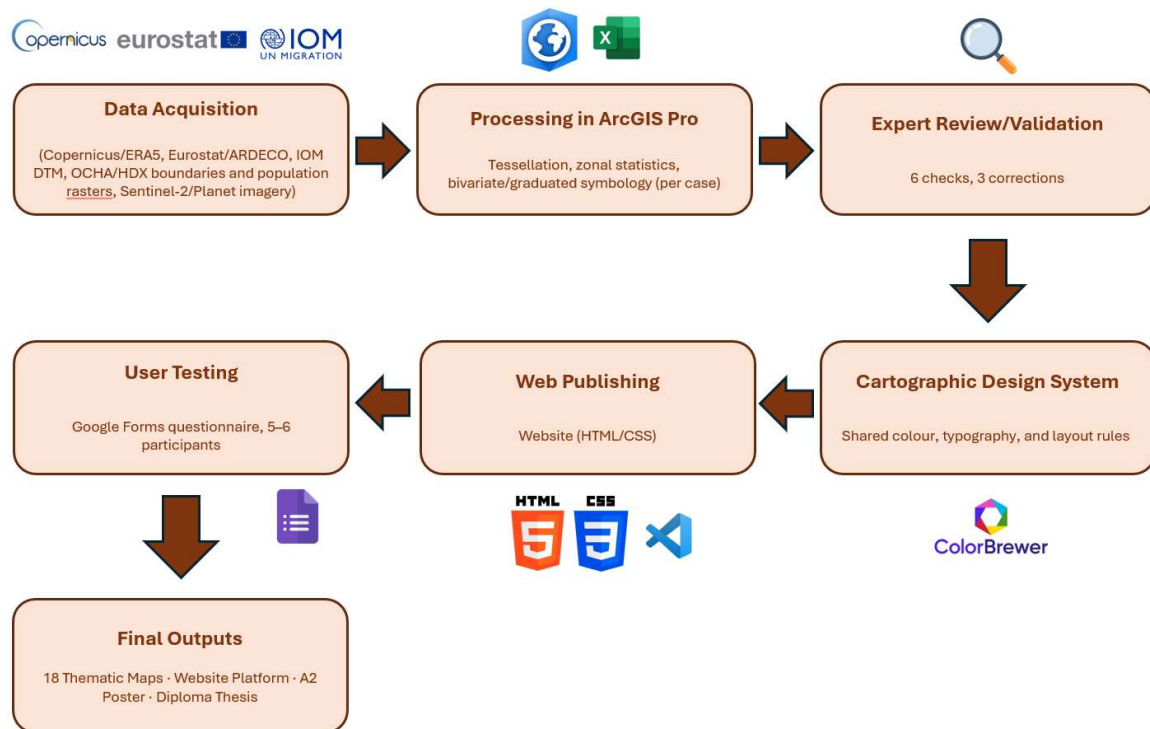


Figure 1. All steps and flows from data collection to final outputs have been converted into a chain without any branches.

3.1 Used data

Chapter 2 (State of Art) examines different data sources. The specific datasets selected for this thesis are described below, organized by platform, and then summarized in Table 1. Different data sources are examined in depth in Chapter 2 (State of Art). Furthermore, how and in what way the selected datasets were used for the thesis is explained in the following sections, and finally, Table 1 summarizes all of this more clearly. For the European case, NUTS3 regions classified as urban type 1 are treated as a proxy for Functional Urban Areas (FUAs), following Eurostat's territorial classification system.

3.1.1 Census Grid

The Census Grid supplies the total-population raster behind the Human Canvas map (§4.1), aggregated per tessellation cell to produce the Wurman-dot effect.

3.1.2 Copernicus (Climate Data Store and Land Monitoring Service)

Two Copernicus services provide the climate-stress evidence behind the Climate Stress Grid (§4.2): the Climate Data Store supplies ERA5-Land monthly averaged reanalysis data

(2m temperature), downloaded as NetCDF, for the 2015–2025 baseline and the 2018/2022 shock years (Muñoz-Sabater et al., 2021), and the Land Monitoring Service supplies NDVI composites for the same years. Both are official, freely accessible Copernicus products, requiring registration but no licence fee. The Climate Data Store portal page for this ERA5-Land dataset is shown in Figure 2.

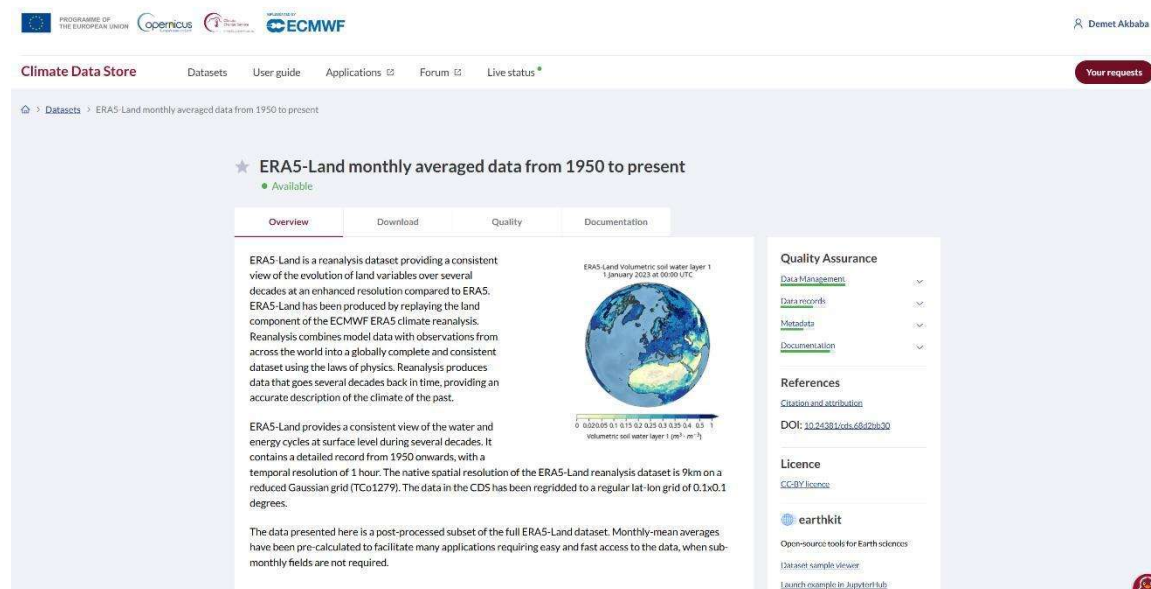


Figure 2 Copernicus Climate Data Store, ERA5-Land monthly averaged dataset page, source of the temperature data behind the Climate Stress Grid

3.1.3 Eurostat

Eurostat supplies the NUTS3 regional boundary layer used across every Europe map (Human Canvas, Climate Stress Grid, Economic Magnet, Demographic Heartbeat), the urban type 1 classification used as the Functional Urban Area proxy, and the population/employment figures used to construct the Economic Magnet's employment-ratio field. The employment figures are Eurostat-produced data accessed through the ESPON (European Spatial Planning Observation Network) portal, which redistributes harmonised Eurostat regional statistics; ESPON is therefore the access portal, and Eurostat the data producer, for that component.

3.1.4 ARDECO (Annual Regional Database of the European Commission)

ARDECO supplies the "net migration by broad age group per 1,000 persons" series behind the ten-year Demographic Heartbeat sequence (§4.4), a pre-calculated, standardised rate rather than raw immigration/emigration counts, which is why no separate gross-flow reconciliation was required (§4.4).

3.1.5 IOM / OCHA

The International Organization for Migration's Displacement Tracking Matrix (DTM), Malawi Multi-Sectoral Location Assessment, Cyclone Freddy Round 1, supplies the origin-destination flow counts behind the Malawi Displacement Flow map (§5.1). OCHA supplies the Admin3 boundary layer used for both Malawi maps, and its Humanitarian Data Exchange (HDX) portal additionally supplies the 2020 and 2025 population density rasters behind the Malawi Bivariate Susceptibility map (§5.2). The IOM Displacement Tracking Matrix and OCHA data portals used for these datasets are shown in Figure 3.

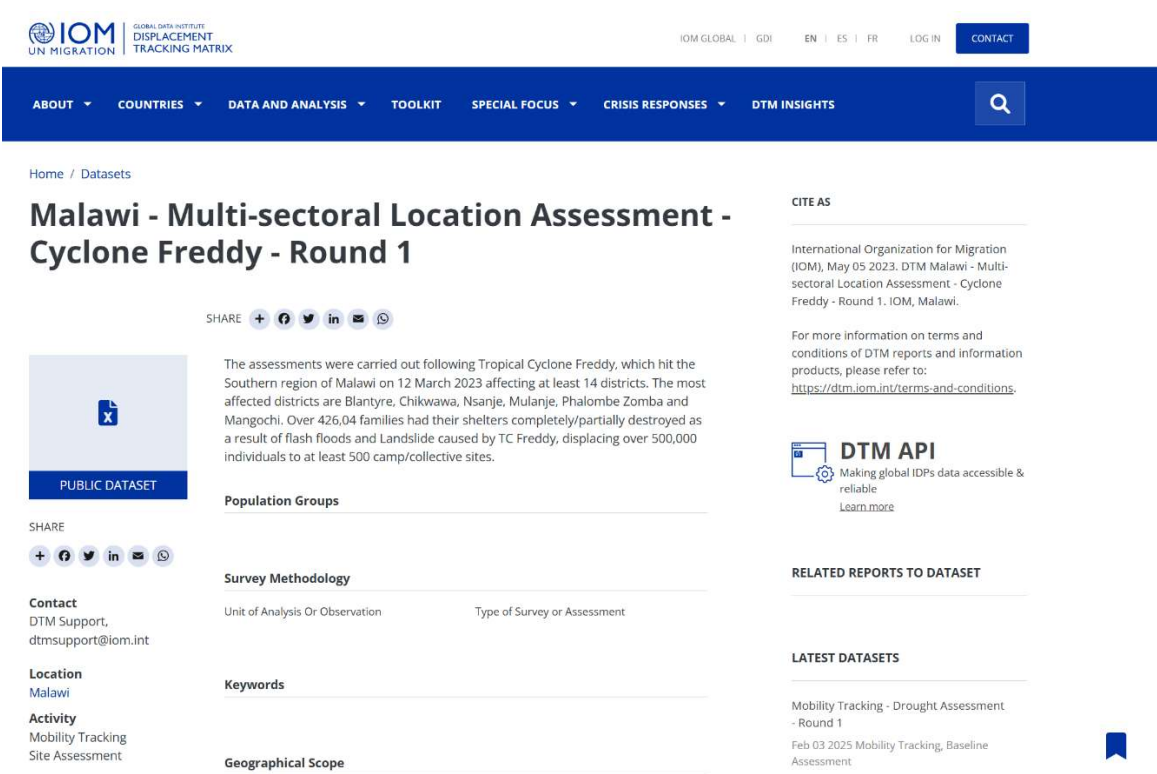


Figure 3 IOM Displacement Tracking Matrix and OCHA data portals.

3.1.6 Sentinel-2 and Planet Optical Imagery

Sentinel-2 is the Copernicus programme's high-resolution optical Earth-observation mission (Drusch et al., 2012), and Planet operates a commercial constellation of small satellites providing frequent, high-resolution optical imagery (Planet Team, 2023). No ready-made vector dataset of landslide occurrence exists for the Southern Malawi study area, so this evidence was built directly for this thesis: Sentinel-2 imagery, supplemented by Planet imagery, immediately before and after Tropical Cyclone Freddy (March 2023) was loaded as image layers and visually compared directly within ArcGIS Pro, and areas showing clear landslide damage (exposed soil, scarp features, and vegetation loss absent from the "before" image) were manually digitized in the same environment as more than one thousand individual polygons. These polygons form the input feature class behind the landslide-exposure variable of the Malawi Bivariate Susceptibility map (§5.2), representing a documented inventory of Cyclone Freddy landslide occurrence rather than

a predictive susceptibility model. Figure 4 shows an example of the Sentinel-2 imagery before and after the cyclone, with the digitized landslide-occurrence polygons overlaid.

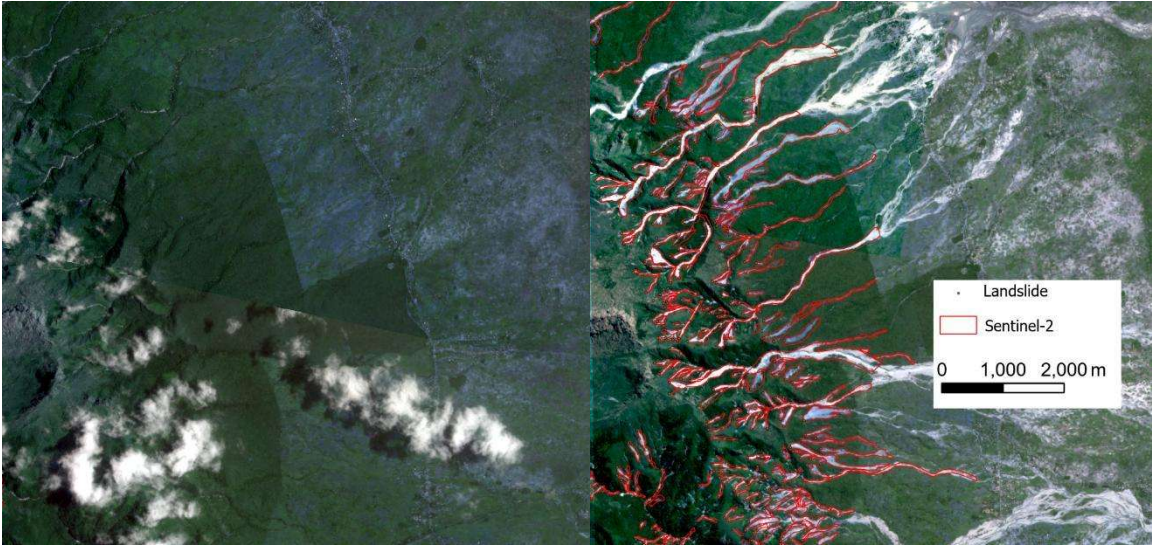


Figure 4 Sentinel-2 imagery of the Blantyre hillside area, Southern Malawi, before (left) and after (right) Tropical Cyclone Freddy (March 2023), with the manually digitized landslide-occurrence polygons overlaid.

Table 1 Data sources used in this thesis, by platform and format.

Source	Format	Feeds into
Census Grid (Total Population)	Raster	Map 1 — Human Canvas (Wurman Dots)
Copernicus Land Monitoring Service (NDVI)	netCDF	Map 2 — Climate Stress Grid
Climate Data Store (ERA5-Land monthly temperature)	netCDF	Map 2 — Climate Stress Grid
Eurostat (NUTS3 boundaries)	Shapefile	Maps 2, 3, 4
Eurostat population/employment (employment accessed via the ESPON portal)	CSV	Map 3 — Economic Magnet

IOM Displacement Tracking Matrix (DTM), Malawi MSLA, Cyclone Freddy Round 1	CSV	Malawi Map 1 — Displacement Flow
OCHA Admin boundaries (Malawi)	Shapefile	Malawi Maps 1, 2
Population density rasters 2020/2025 (via OCHA HDX, Malawi)	Raster	Malawi Map 2 — Bivariate Susceptibility
Sentinel-2 / Planet before-after imagery (digitized landslide polygons, Malawi)	Polygon (self-digitized)	Malawi Map 2 — Bivariate Susceptibility

All sources are legitimate, citable, official or open-data sources (Copernicus, ERA5/Climate Data Store, Eurostat, ARDECO, OCHA, GHSL, Sentinel-2, Planet); the landslide-occurrence polygons were digitized by hand from before/after Sentinel-2 and Planet imagery rather than downloaded as a finished vector dataset.

3.2 Software Used and Platforms

3.2.1 ArcGIS Pro

ArcGIS Pro is Esri's desktop geographic information system application, integrating spatial data management, raster and vector analysis, and cartographic design within a single environment. It is the primary GIS software used throughout this thesis: all raster processing (tessellation, zonal statistics, raster calculation), vector processing (spatial joins, dissolves), cartographic symbology (graduated symbols, choropleth, bivariate colour), and layout design for all 18 maps were carried out in this software.

3.2.2 QGIS

QGIS is a free, open-source desktop GIS application, offering data viewing, editing, and analysis functionality broadly comparable to commercial GIS software. To ensure independent layer integrity checks, it was used multiple times during data preparation; since the resulting files were published to the web, they were opened and validated as GeoJSON before being moved to ArcGIS Pro. This prevented any formatting issues from occurring and detected them early.

3.2.3 Google Forms

Google Forms is one of the most widely used browser-based survey design tools and is also a very useful tool for visualizing responses to closed-ended questions. It also allows for the creation, distribution, and, most importantly, analysis of surveys. In this thesis, the graph analysis it provides was used directly, providing quick results without the need for any expert calculations. It is also preferred over any GIS-specific survey product because it does not require tethering to any particular GIS platform.

3.2.4 GitHub

GitHub is a web-based platform used for version control and also hosts code repositories. In addition, it publishes static or client-side web content directly from a repository, and this is collaborative. This platform was used for this master's thesis to independently and publicly share the completed web map platform and supporting code.

3.2.5 Canva

Canva is a browser-based graphic design platform that offers plenty of freeform and templated layout tools to create visual content (infographics, posters, etc.) without the need for specialised graphic design software. This was the method used to generate the A2 poster supplement, which is a requirement for submission for this thesis, therefore presenting the objective, workflow, outcomes, and contribution of the thesis on one page, fulfilling the requirements of the department template.

3.2.6 Artificial Intelligence Tools

During the preparation and writing phases of this thesis, artificial intelligence tools were used to assist with writing and editing. Their uses included: correcting the language of written texts, ensuring clearer writing, improving any structural problems, and most importantly, supporting reference checking. The entire research design, all spatial analyses performed, data collection, processing and manipulation, obtaining and interpreting the results, are all the author's own work. Each chapter written with the support of artificial intelligence has been thoroughly reviewed by the author, and necessary adjustments have been made. Furthermore, the author is fully responsible for the content created. This is also stated in the introduction of the thesis.

3.3 Cartographic Design System: Harmony Within and Across the Two Cases

One of the core ideas this thesis attempts to convey is that consistency between maps isn't simply about them being well-designed. In Segel and Heer's (2010) narrative visualization framework, as planned and implemented in this thesis, a series of maps are treated as a single, directed story. For this story to be meaningful and useful, there needs to be a connection between the map being examined and the next map, and this visual language needs to be transferable between them: just like Bertin's (2010) example of how to consistently and stably encode information on a single map. The design system developed for this platform operates at two levels: strict internal harmony within each

case study, and a deliberate, explained register shift between the two cases, reflecting the fact that slow-onset drought migration in Europe and rapid-onset cyclone displacement in Malawi are genuinely different phenomena rather than a single pattern viewed twice.

Within the Europe case: Every one of the 16 Europe maps is built from the same custom colour hierarchy rather than a photographic or street basemap. A World Countries layer (Esri Living Atlas) is filled in a warm gold (#FFDA87), and the map background is held in the same warm family (#FFEbbe, at 31% transparency), so that base geography and canvas recede together as a neutral, muted context. Against this warm canvas, the countries that form the actual unit of analysis are filled in white (#FFFFFF) with a dark brown outline (#895A44) across 14 of the 16 maps, deliberately the strongest contrast on the page, since these boundaries are analytically the most important feature on every map regardless of which variable that particular map encodes, and the same muted brown already used for the platform's typography (below), unifying map and text into one restrained palette. This rule is not applied to the two Climate Stress Grid maps specifically: their bivariate matrix already fills each cell in comparatively dark tones, against which a brown outline would lose the contrast needed to remain legible, so these two maps retain a blue country outline instead for continued visibility against the darker cell colours.

The Demographic Heartbeat series (ten yearly maps) and the Economic Magnet map both use the same ColorBrewer color scale, going from red (#CB181D, #FB6A4A, #FEE0D2) to green (#D9EF8B, #A6D96A, #1A9850, #006837). These carefully and logically chosen colors represent decline and growth for net migration rate and employment rate change. So red means decline, green means growth, and the map reader can easily remember this understanding between maps because this coding is simple. For the Human Canvas wurman dots, a dark brown color (#894444) was used, creating a transition between the background and white while also standing out. This color is in harmony with the map background, the header color, and the backgrounds of the European countries. The rectangle in the upper right corner, which emphasizes population change, was also given the same color, thus highlighting similar aspects intended to be emphasized on the map, without creating clutter and chaos by adding too many color combinations.

The Climate Stress Grid uses a nine-color grid (#365D8A, #8EA7C2, #E6E6E6 / #5E4876, #A28B9E, #D1989E / #793260, #A95D6F, #BA3232). The color range is quite wide just for this map, and this was actually done and designed intentionally because two different phenomena, temperature and NDVI, needed to be shown simultaneously and continuously. The most accurate cartographic approach for this was to use a bivariate map and this wide color scale. Even here, it's used to identify the worst stress combination (#BA3232), which is quite consistent with the overall design applied to the platform because showing it with a red tone is quite memorable if we want to signal the most extreme case.

The color palettes used and their harmony are shown more closely in Figure 5 with the legends and graphs of the Demographic Heartbeat and Economic Magnet maps.

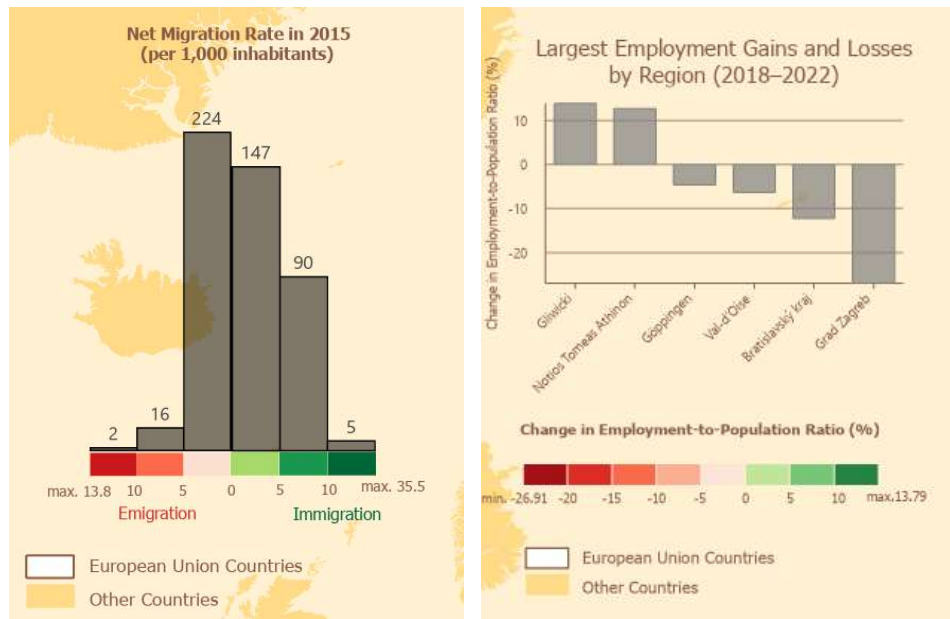


Figure 5. The legends for the Demographic Heartbeat and Economic Magnet maps use the same color palette taken from ColorBrewer; therefore, in both legends, red indicates decline and green indicates growth.

Typography and layout reinforce the same hierarchy independently of colour. All Europe maps share Tahoma Bold, 24 pt main titles and Tahoma Bold, 18 pt subtitles, with the year label set in Tahoma Bold, 18 pt in a muted brown (#895A44); all body and reference text is Tahoma Regular, 10 pt, in the same #895A44 tone, deliberately desaturated relative to the already-colourful legends and symbology so that text recedes rather than competing for attention. Every map uses the same title design (a header box in #FFAA00 with 33% transparency), places the legend in the same spot (bottom-left, below the description or chart), and keeps a fixed 5 cm margin on every side. Scale and orientation follow the same logic: all Europe maps use an identical, simple north-arrow and scale-bar style at a fixed reference scale of 1:19,500,000, chosen specifically because it is the smallest scale at which Cyprus and Portugal, the continent's eastern and western extremes, both remain on the page with the composition centred. The same typographic treatment extends to the non-spatial charts embedded in each map, as shown in Figure 6.

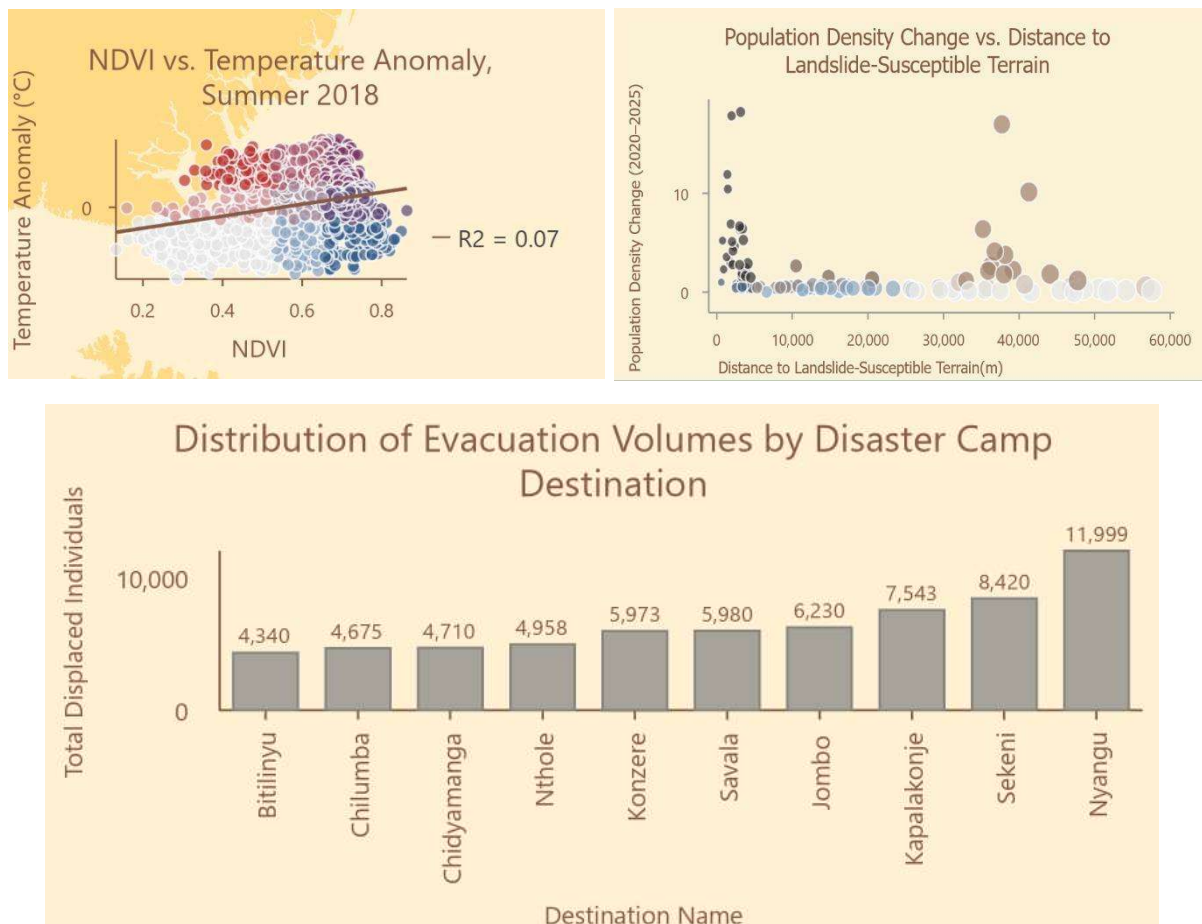


Figure 6 The non-spatial data visualisations embedded across the map suite: histogram, scatter plots, and bar chart share the same Tahoma typography and muted brown (#895A44) text tone as the maps that carry them.

Between the two cases: The two Malawi maps (Displacement Flow and Bivariate Susceptibility) form their own internally consistent register: a shared orange header banner and cream background in the same broad warm family as the Europe canvas (maintaining a family resemblance across the whole platform), a consistent top-left north arrow and bottom-left attribution block, and a mirrored map-left/description-right layout rather than Europe's map-centred, text-above, legend-bottom-left grid. This style is meant to be different from Europe's style, not the same. Europe's case is about slow change over ten years across many countries, so it uses a calm, quiet white-and-brown design, made for comparing lots of similar maps side by side. On the other hand, the situation in Malawi is quite different: a sudden and devastating event concentrated in one region. Therefore, the type of displacement experienced in this catastrophic situation also has its own unique layout. However, because it uses the exact same style in terms of design, font, and source citation, it very clearly belongs to the same platform. The only difference is that instead of all the maps being placed side-by-side for comparison, the severity of the Malawi incident is emphasized. Figure 7 compares the headings of the maps from the two different incidents and shows how the Malawi maps both maintain the common typography and reflect the level of importance.

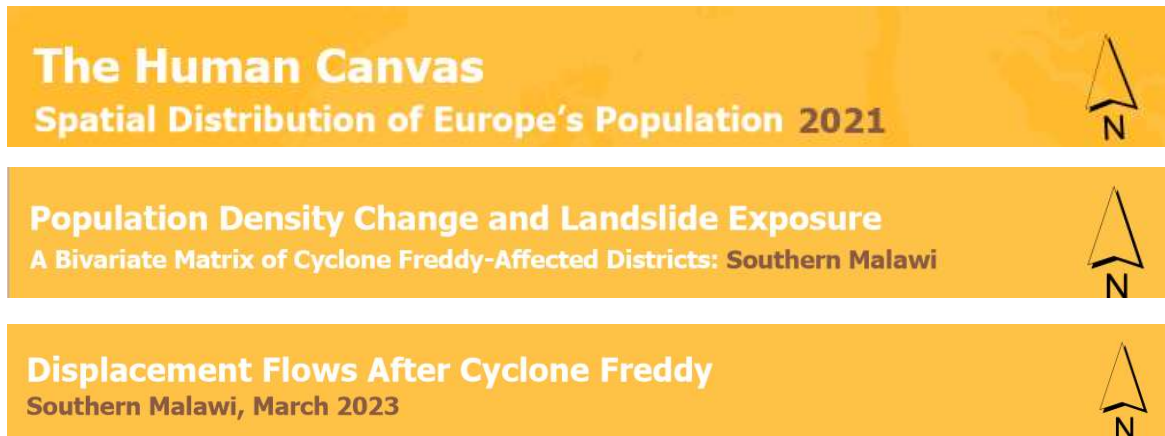


Figure 7. Title designs from two different cases: One map from Europe (The Human Canvas, top) and two maps from Malawi (Bivariate Susceptibility, middle; Displacement Flow, bottom). All three headlines share the same colour, font size, and text size.

Bivariate Susceptibility Maps and Climate Stress Grid Maps, when produced using the same technique, share the same type and technique of legend. Unlike Europe's red-orange-grey-purple color combination, the Malawi example uses blue and brown/beige because these colors represent landslides and population change; the things being compared are quite different: for the European example, vegetation and temperature, while in Malawi, proximity to landslides and population change.

The Displacement Flow Map, however, uses a completely different color scale. It uses a scale ranging from red to orange to show the movement from the landslide area towards the camp locations. This is a fairly standard practice for displacement Flow maps, but it's not simply a choice different from European maps. However, this choice is not an aggressive one against the overall design of the platform; strong and warm colors reflect important values.

Across the full 18-map suite, only this Displacement Flow map uses an actual basemap (a muted, Dissolve-simplified terrain layer, needed because the flow lines require real topographic and settlement context); every other map (all 16 Europe maps and the Malawi Bivariate Susceptibility map) is built entirely from custom vector fill layers, keeping the platform largely free of basemap noise. Figure 8 shows the diamond legend reused across the two cases, recoloured to each map's own variable pair.

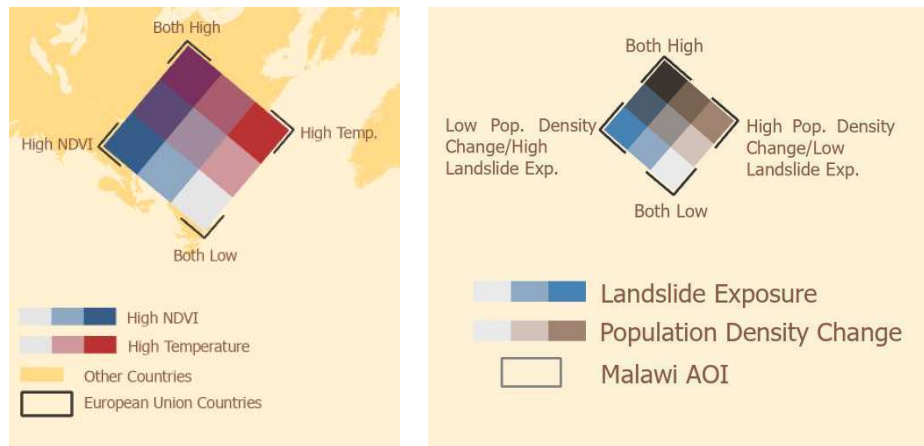


Figure 8 One bivariate technique, two palettes. The diamond legend is reused across the two cases, recoloured to each map's own variable pair: purple–grey–red–orange for temperature and NDVI (Europe), blue and brown/tan for landslide exposure and population change (Malawi).

One deliberate limit to this harmony should be stated explicitly: proportional-symbol and legend sizing was not standardised to a single fixed scale across all 18 maps. Each map's graduated symbols and legend classes were instead calibrated individually by reviewing the layout at 100% export size, ensuring legibility at final output resolution rather than forcing dissimilar map extents and phenomena (a continent-wide hexagon grid against a single-region district map, for instance) onto one arbitrary symbol-size standard that would not serve either well. Harmony in this design system therefore operates at the level of colour, typography, and layout grid, which are held constant by fixed rule, rather than at the level of absolute symbol size, which is calibrated per map for legibility.

Read together, these choices support rather than merely decorate the thesis's central argument. A fixed, restrained colour-and-type vocabulary within each case lets a reader carry meaning from one panel to the next without re-learning it, consistent with Segel and Heer's (2010) account of how a narrative visualisation sequence is read; the deliberate, explained register shift between the two cases signals, visually, that a genuinely different phenomenon is being examined, reinforcing rather than undermining the dual-space framing developed in the Objectives and State of Art.

3.4 Web Publishing: From ArcGIS Pro to Website

Presenting the maps designed for the platform in a fixed and sequential manner and following a suitable design was planned from the outset. At this point, an interactive web map has not been published; instead, the completed maps have been saved as high-resolution static images.

18 maps have been exported and edited in a way that does not violate the rules of the thesis and chapter website. They are then placed under two different headings on the website, in a way that will catch the reader's eye, following a specific order. The website is divided into two separate headings: European and Malawi studies, and the maps for these headings are positioned in an organized manner. The slow-onset migration in Europe is explained in detail in section (§4.1–4.5). This is followed by the rapid-onset

section (§5.15.2) for Malawi. The chapters of the website are created from explanations taken from the relevant sections of the thesis and highlight the maps. It does not include all the technical details of the analyses performed. The website is not intended to replace or prefer the methods described in the thesis; its purpose is to share the results with policymakers and planners and to provide support as an administrative output. Throughout the website, section dividers, text blocks, headings, etc., use the same colors and fonts, maintaining consistent layout. This ensures that the website does not give the impression of being a downloaded template, but rather a part of a unique design. Figure 9 is a section of the Demographic Heartbeat data taken from the website; the link to the website also follows in the description.



Figure 9 [Website](#) interface from the perspective of Demographic Heartbeat: map aligned with small text

3.5 Poster

The poster, a requirement for thesis submission (see Attachments), covers the two main case studies of the thesis, Europe and Malawi, and some of the maps produced for these cases. The texts are created using explanations taken from the sections of the thesis such as objective, methodology, results, and discussion, and aim to summarize the findings in a single page. Canva (§3.2.6) was used for the design, and the poster structure comprises four main sections: Objectives, Methods and Workflow, Results, and Contribution of the Study (Objectives; Chapter 3 and §4.1–5.2; Chapter 6; Chapter 8).

3.6 Quality Assurance: Expert Review and Validation

Throughout the validation process, two separate objectives were focused on; the first objective was to ensure the accuracy of the numbers: were the figures accurately taken from the thesis' sources and calculated precisely? The second objective was to question how logical these values were. This can also be called an expert review, meaning, in short, a comparison was made between the numbers, the data taken from the source, and also with external references. This does not count as field validation, as that would involve comparing with field data, which is not the purpose of this thesis. Overall, two case studies were considered and six controls were performed. (Table 2). Three passed without any problems, while the other three showed real processing errors that had to be fixed. This shows that the validation process was a real part of the work, not just something done once and forgotten.

Table 2 Expert review and validation checks carried out across the two case studies

Check	Value	Result
SE110 (Stockholm county, Sweden), 2016 net migration	24,077 (ARDECO)	Passed the raw ARDECO CSV was checked directly, and the value was confirmed identical.
Southern Malawi displacement total, 2023	190,683 across 21 origins and 153 destination locations (IOM DTM Round 1)	Passed the value reconciles independently between the origins table and the destinations table, both computed directly from the flow-level data. It is lower than published national situation-report totals (approximately 362,928–659,278) because it reflects IOM DTM's site-based tracking specifically, not all displacement nationwide a methodologically narrower but legitimate measure, not an error.

Climate Stress Grid (2018), NDVI vs. ERA5 temperature independence	—	Error found and corrected. The initial Zonal Statistics output showed NDVI and temperature-anomaly values identical for every one of 2,170 hexagons, indicating the same input raster had been reused across both statistics runs. Diagnosed as a reused-tool-dialog error; re-running the tool with the NDVI raster explicitly re-specified as input produced physically plausible, independent NDVI values (0.13–0.86).
Malawi Displacement Flow, origins vs. destinations independence	—	Error found and corrected. The destinations layer was found to be byte-identical to the origins layer the same reused-export error as above. Re-dissolving the flow table by the destination field specifically, and cross-referencing the site-name lookup table, produced genuinely distinct destination totals (e.g., Nyangu School, 11,999; Sekeni Camp, 8,420) that still reconcile to the same 190,683 grand total.
Malawi Bivariate Susceptibility, landslide-exposure direction	—	This error was found and fixed. The Euclidean Distance raster, which measures exposure, gets bigger the further away you are from hazard-prone land. So, before it was fixed, it wrongly showed low-risk rural districts (Chikwawa, Mwanza, Neno) as the most exposed, and the actual wards where people died in the March 2023 landslides (Ndirande, South Lunzu, Chilomoni, Soche West, all in Blantyre City) as the least exposed. To fix this, the values were flipped before reclassifying them. After the fix, the map correctly shows high exposure almost entirely within Blantyre City, which matches what actually happened in the disaster

National and district-wide displacement totals for Malawi varied substantially by report date and methodology during the emergency response: totals ranged from approximately 362,928 to 508,000 to 659,278 across different situation reports within weeks. A mismatch between the thesis's own figure and any single published total does not necessarily indicate an error.

Two of the three corrected errors trace to the same underlying cause: reusing an ArcGIS Pro tool's dialog or export settings across two runs without updating the one input parameter that actually changes between them: a second Zonal Statistics run reusing the first run's raster, and a second layer export reusing the first layer's selection. The third, the landslide-exposure inversion, reflects a distinct but equally recurring pitfall: a distance-based proxy (Euclidean Distance) and the concept it is meant to represent (proximity or exposure) run in opposite directions unless the raster is explicitly inverted before use, and neither the legend text nor the symbology flags this mismatch on its own. Both lesson types are recorded here explicitly, since GIS workflows built from reused-parameter operations or generic distance surfaces carry a specific, recurring risk of silently encoding the opposite of what was intended.

3.7 Method Limitation

The biggest limitations are threefold: data heterogeneity, since all data could not be sourced from a single platform; processing time, since NDVI and ERA5 raster processing was large and slow; and validation uncertainty, since there is no independent way to confirm map accuracy beyond supervisor review and the six expert review and validation checks above. The end-stage user testing of the platform is intended as a partial mitigation of this last limitation.

3.8 Reviewer-Criticism Response

The biggest risk identified is that juxtaposing the Climate Stress and Economic Magnet maps (or any push/pull pairing) side by side visually implies a causal relationship to the reader, even though no statistical test is performed. This platform is explicitly descriptive, not causal. Each map is methodologically independent; their juxtaposition is a storytelling device, per Segel and Heer's narrative visualization framework, meant to prompt the reader's own interpretation rather than assert that climate stress directly causes the migration shown alongside it. In other words, no statistically valid relation has been proposed or tested.

A second, less significant concern is the comparability of Malawi's single-event Admin3 monitoring system versus Europe's multi-annual NUTS3 panel; this has been assessed using a dual-pace framing, the two different study areas have been deliberately contrasted, and no statistical proof has been promised.

3.9 User Testing Methodology

Per the Objectives (Chapter 1), urban planners and policy makers are both the platform's intended audience and the intended participants in its end-stage user testing. This subsection describes the planned method; the actual participant count, questions asked, and findings are reported in Chapter 6 (Results) once testing has been carried out. User testing evaluates the platform as a whole, both the Europe and Malawi sequences together, which is why it is documented here as part of the overall method rather than folded into either individual case-study chapter.

Because of the limited time and scope of this thesis, the user testing was designed as a small, informal check of usability and understanding, not as a statistically representative study. This limitation is clearly stated here, rather than left unspoken.

Participants: Six people took part in the test, picked on purpose from three different groups rather than just one type of user. Since each group only has one to three people in it, these results should be read as a small sample of viewpoints, not as numbers that represent a wider population.

First, one urban planner, since planners are the main people this platform is made for. Second, two academic reviewers from related fields at the author's university, who acted as informal experts checking the maps and the science behind them. Third, three volunteers with no background in GIS or planning, who checked whether the platform was easy to read and follow. If someone with no special knowledge can still make sense of the platform, that tells us the symbols and legends are doing their job on their own, without the reader needing to already know the subject. Each person's background was written down next to their answers, since a group this small and mixed can't be lumped together as if everyone were the same.

Method: The test was carried out remotely, with each person working through it on their own time. Every participant was sent a link straight to the live website, not printed maps, since the website itself is the actual deliverable, along with a short survey to fill out after they'd looked through it on their own. The survey had three parts:

1. *Task-based comprehension questions*, where people had to point out one exact answer on a named map, rather than just giving their general opinion. For example, they were asked to find where climate stress was worst in 2022 on the Climate Stress Grid, which years showed the sharpest rise in people leaving after the 2018 drought on the Demographic Heartbeat map, and which city the displacement destinations mostly clustered around on the Displacement Flow map. The full list of questions, answer choices, and the correct answers used for scoring is included as an attachment (Attachment 19). The point of these questions was to see if the colors and legends got the main idea across clearly, not to check whether people already agreed with that idea.

2. *Design questions* on a five-point scale (from strongly disagree to strongly agree), covering how clear the map colors and legends are, whether the Europe and Malawi maps feel like they belong to the same platform even though they look a bit different on purpose (§3.3), and how much people would trust the platform for an actual planning or policy decision.

3. *One open-ended question* asking what, if anything, felt confusing or could be improved."

The full wording of every question is included in the Attachments, along with the answer options for the task-based questions and the answer key used for scoring. This way, the results reported in Chapter 6 can be checked against the exact questions that produced them. One question deserves special mention here: participants were asked directly whether the platform claims that climate stress causes the migration shown. This question was designed to check whether the descriptive, non-causal framing (§3.8) actually reaches the reader, instead of only existing in the thesis text

Survey platform: Google Forms is used rather than a bespoke instrument or a GIS-specific survey product, since it requires no separate account for respondents, keeps the survey instrument independent of any single GIS vendor's platform, and produces automatic summary charts of the closed-question responses, avoiding a manual tallying step for a study of this size.

4 EUROPE CASE STUDY

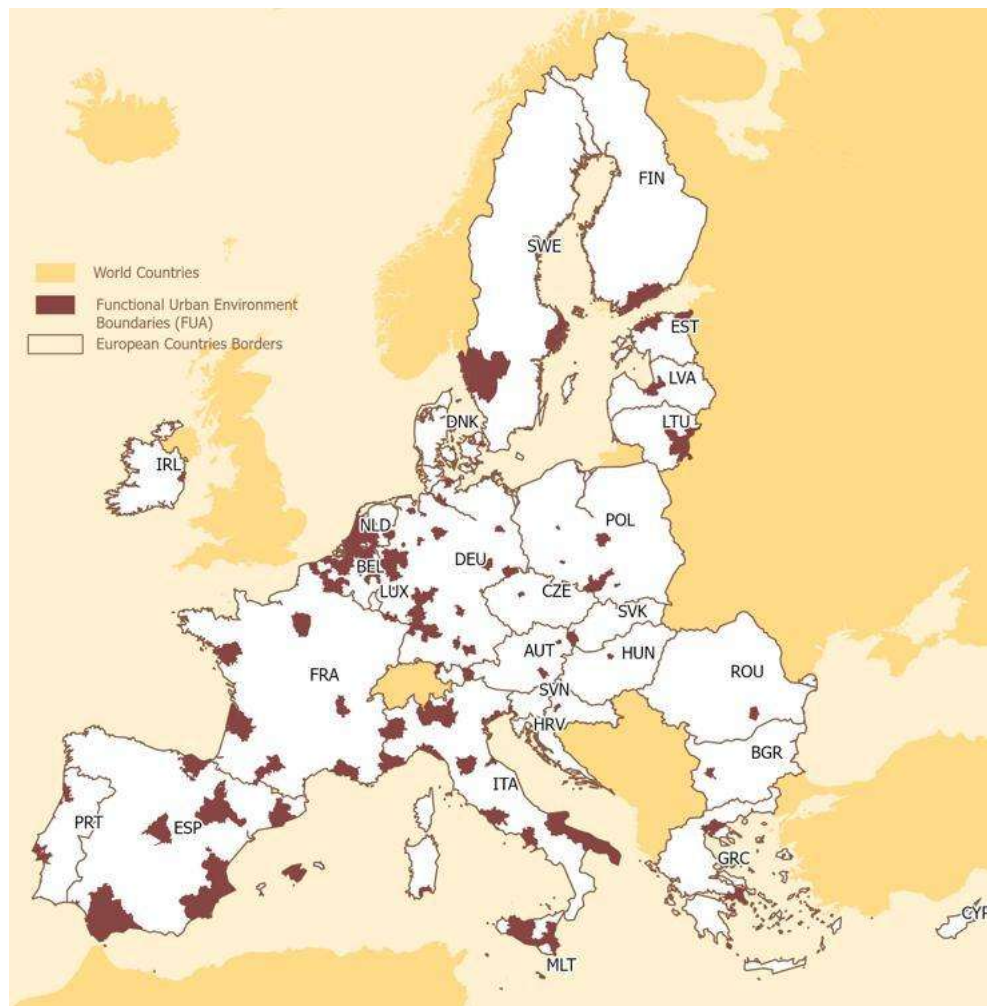


Figure 10 Study area: EU member states and NUTS3 urban type 1 (Functional Urban Area) regions used across all Europe case study maps

4.1 Human Canvas: Population Density (Wurman Dots)

Used Data: Population Census Grid (Total Population), raster.

Polygons of European Union countries from the Esri Living Atlas were first merged and corrected into a single boundary layer using the Merge tool. Then a regular tessellation was built on this boundary, and the population raster data were transformed into point features in each tessellation cell. Next, the Summarize Within tool was used to sum the total population per cell. Finally, the Feature to Point conversion tool generated cell-centre points representing the summed population value. These points were then displayed as graduated symbols scaled to population size, producing a Wurman-dot effect. In this way, symbol size reflects the relative population density without the visual distortion of a filled-area choropleth.

The finished map reproduces the "Blue Banana" or European Megalopolis pattern long documented in European population geography: the densest concentration of Wurman dots forms a continuous corridor running from the Rhine-Ruhr region (Netherlands,

Belgium, and western Germany) through the Paris Basin and down into northern Italy's Po Valley, with the single largest individual cell centred on Paris (11.8 million people). The Rhine-Ruhr cluster is the densest single region on the map, with fourteen adjacent tessellation cells together holding over 49 million people, more than any other cluster, including the Paris Basin itself. Secondary but still visually prominent clusters appear around Madrid, Barcelona, Poland's Warsaw–Katowice–Kraków urban belt, Vienna, Hamburg, Athens, and Budapest, each forming a distinct, isolated dot cluster set against comparatively sparse rural symbol density elsewhere on the map. Because the underlying boundary layer is restricted to European Union member states, the United Kingdom, which would otherwise form part of this same north-western European density corridor, does not appear. Figure 11 shows the Wurman-dot density over the Rhine-Ruhr corridor, the single densest cluster on the finished map.

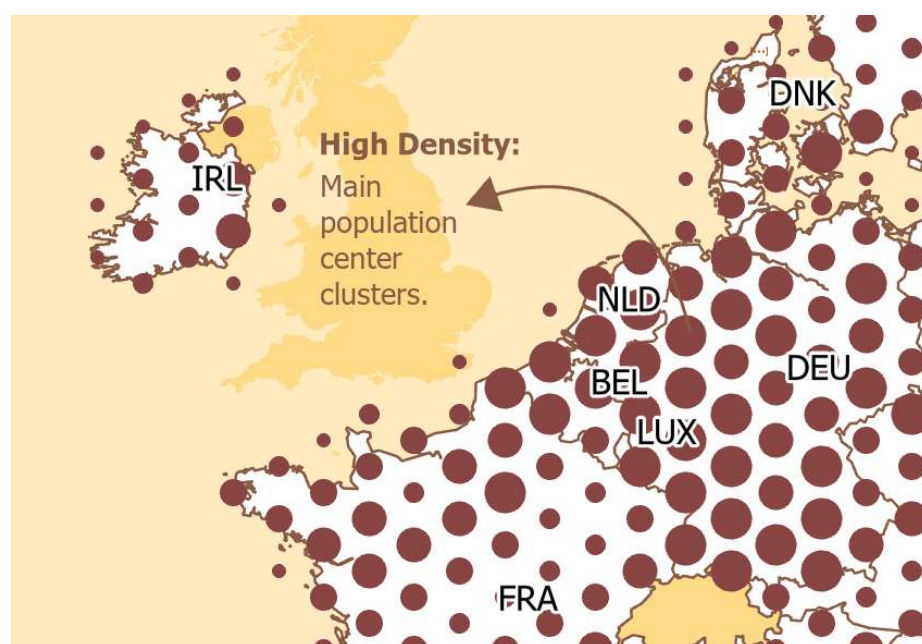


Figure11 Wurman-dot density over the Rhine-Ruhr corridor, the single densest cluster on the finished map (49 million people across 14 adjacent tessellation cells).

This map establishes the population baseline against which climate stress (4.2) and migration patterns (4.4) are later compared: areas of high population concentration are, by definition, areas where even small relative migration changes represent large absolute numbers of people.

4.2 Climate Stress Grid (2018 and 2022)

Used Data: ERA5-Land monthly averaged temperature data (Climate Data Store, §3.1.2) for June–August (JJA) of 2018 and 2022, plus a 2015–2025 long-run temperature baseline, and NDVI August composites (Copernicus Land Monitoring Service) for the same two years.

Used Data: ERA5-Land monthly averaged temperature data (Climate Data Store, §3.1.2) for June–August (JJA) of 2018 and 2022, plus a 2015–2025 long-run temperature

baseline, and NDVI August composites (Copernicus Land Monitoring Service) for the same two years.

Temperature anomaly was calculated by first computing the JJA mean temperature for each of 2018, 2022, and the full 2015–2025 baseline period, using the Multidimensional Summary Statistics tool's mean function on the monthly averaged ERA5-Land data. The Minus tool was then used to subtract the baseline mean from each event year's mean, producing two anomaly layers: 2018 anomaly and 2022 anomaly. NDVI was processed separately: three NDVI composites for August of each event year were combined using the Cell Statistics tool's mean function, producing a single August-mean NDVI layer per year. Since both the temperature and NDVI layers had to use the same coordinate system, they were modified. Subsequently, using the Extract by Mask method, these layers were adjusted based on the borders of the European countries that constitute the study area. Then, a grid was created in the form of regularly generated hexagonal groups, each 1000km wide. This step was the most important step of the Bivariate Map. Afterwards, the Zonal Statistics table tool was used to place the average temperature and NDVI values inside these hexagons, and all these values were added to the attribute table of this layer. Color codes that would best represent temperature anomalies and NDVI were researched, and red-purple tones were considered suitable for these two phenomena, and these colors were assigned to the hexagons. This made it possible to clearly distinguish between hexagons with both high NDVI and high temperature anomalies, as well as hexagons where only one of these is high. In the final step, the NUTS3 boundaries were kept in dark color and placed on the grid. All these steps were repeated sequentially for the years 2018 and 2022.

The Climate Stress 2018 map replicates a pattern documented in the literature as "warmer drought": for example, we can observe that high temperatures and decreased vegetation health are concentrated in Northern Europe. Almost 39% of the hexagons containing the lowest NDVI (most severe stress category) and the highest temperature anomaly are found in Germany. The remaining 29% are distributed in France, 18% in Scandinavia, and 14% in Poland. This is a repetition of the specific reversal noted by Buras et al. (2020) for the 2018 shock year. This is not a Mediterranean-dominated model, as is typical in European drought years, but rather a model where drought unexpectedly intensifies in northern and central Europe.

The 2022 map strongly supports what the Joint Research Centre has said: that 2022 likely witnessed the most severe European drought in the last five centuries, with 47% of Europe under drought warning and the remaining 17% at risk of drought alert by August of that year. This map is consistent with this assessment and also shows us a widespread stress pattern (Toreti et al., 2022). This is borne out directly in the hexagon counts: the number of hexagons meeting the same severe-stress threshold grows by roughly 54% between the two years, and the geographic centre of severity shifts markedly south and west. Where 2018's severe stress concentrated in Germany, France, Scandinavia, and Poland, 2022's is dominated by the Iberian Peninsula (49% of severe hexagons) and France (34%), with a smaller share in Italy (7%), a pattern consistent with Toreti et al.'s (2022) identification of Western and Southern Europe, and Iberia specifically, as the epicentre of that year's drought. The two maps are shown in Figures 12 and 13.

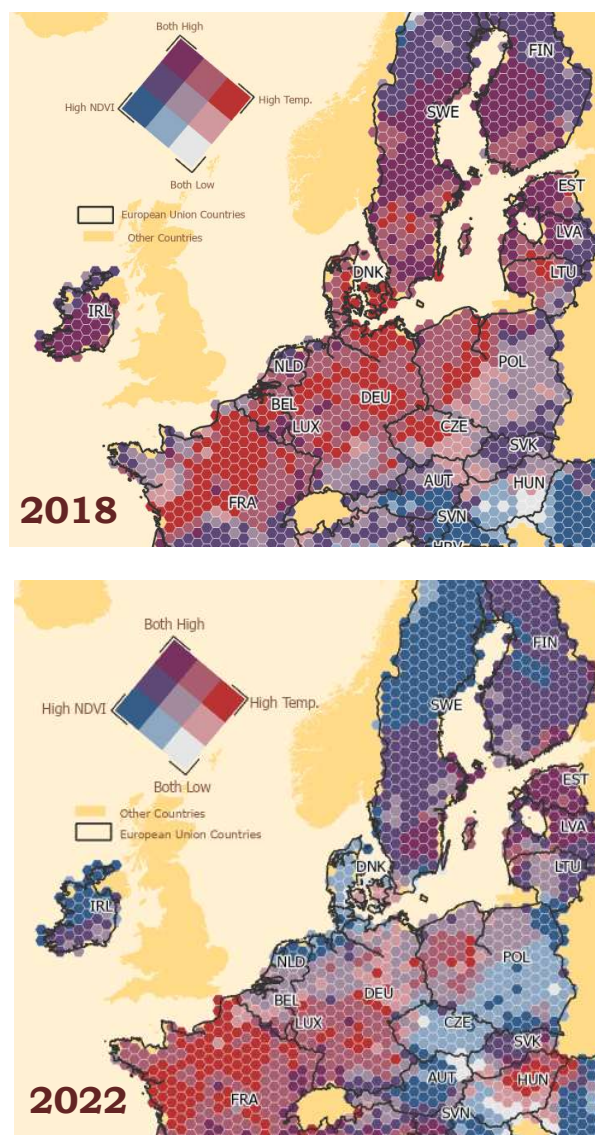


Figure 12 Climate Stress Grid, 2018: severe stress concentrated in Germany, France, Scandinavia, and Poland. Figure 13 Climate Stress Grid, 2022: severity shifts to the Iberian Peninsula and France.

4.3 Economic Magnet

Used Data: ESPON employment CSV, joined to NUTS3 boundaries restricted to "urban type 1" regions (the proxy used for Functional Urban Areas, per Eurostat's territorial classification and Dijkstra et al., 2019).

Employment figures for 2018 and 2022 were joined to the NUTS3 boundary layer, retaining only urban type 1 regions. A new field, employment change, was calculated using the equation:

$$((\text{emp2022}/\text{pop2022}) - (\text{emp2018}/\text{pop2018})) / (\text{emp2022}/\text{pop2022}) \times 100$$

This expresses the percentage change in the employment-to-population ratio between the two years, rather than raw employment change, so that the result reflects shifting

economic density rather than population growth alone. The resulting field was displayed as a choropleth map across the urban type 1 / FUA boundaries.

The strongest positive employment-ratio gains between 2018 and 2022 cluster in southern Poland: Gliwicki (+13.8%) and Katowicki (+13.7%) in the Upper Silesian industrial region, alongside Kraków (+12.1%) and the Tri-City area (Trójmiejski, +12.4%), with one Greek region (Νότιος Τομέας Αθηνών, +12.7%) also among the top five. The steepest decline by a wide margin is Grad Zagreb (−26.9%), roughly double the next-largest decline (Bratislavský kraj, −12.3%), with the remaining losses concentrated in smaller, single NUTS3 regions in France (Val-d'Oise, −6.4%) and Germany (Göppingen, −4.6%; Groß-Gerau, −4.4%). Notably, neither the strongest-gaining nor the steepest-declining regions spatially correspond to the climate-stress hexagons identified in §4.2, which concentrate instead across France, Germany, the Benelux countries, and Scandinavia. This lack of spatial correspondence is consistent with the thesis's broader finding that climate stress and economic/migration indicators do not align mechanically (see §4.4), rather than evidence against the push-pull framing established in the Introduction. Figures 14 and 15 show the Economic Magnet map for north-western Europe and a detail of the strongest-gaining southern Poland cluster.

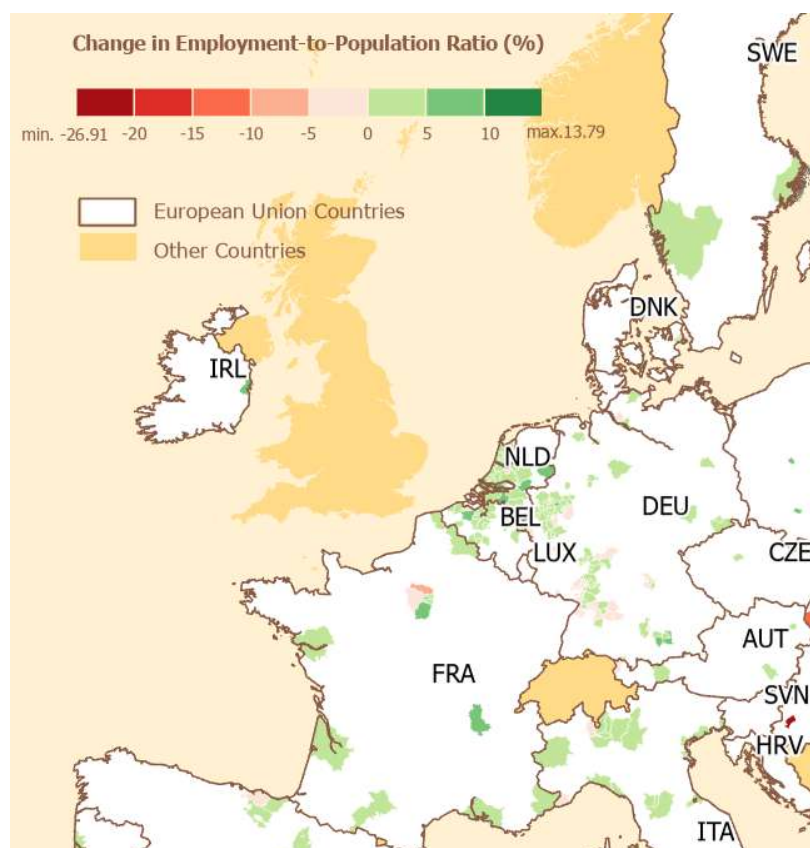


Figure 14 Economic Magnet, 2018–2022 employment-ratio change: north-western Europe, with the diverging legend (red = ratio decline, green = growth).



Figure 15 Economic Magnet, detail of the strongest-gaining cluster: southern Poland (Gliwicki, Katowicki, Kraków), with adjacent Czechia and Slovakia.

4.4 Demographic Heartbeat (ten maps, 2015–2024)

Used Data: ARDECO "Net migration by broad age group per 1,000 persons" (Annual Regional Database of the European Commission), joined to NUTS3 urban type 1 boundaries.

Net migration rate is a standard demographic indicator equal to the difference between the number of people who moved into a region (immigration) and the number who left it (emigration) during a given year, expressed per 1,000 inhabitants of that NUTS3 region's total resident population, so that regions of very different sizes can be directly compared regardless of their absolute population. A positive value means more people moved into the region than left it (net inflow); a negative value means more people left than arrived (net outflow).

ARDECO net migration rate figures were joined to the NUTS3 (urban type 1) boundary layer using a standard table join. Since the ARDECO dataset already gives the net difference between immigration and emigration, standardized per 1,000 people, there was no need to work out the gross flows separately. For each year from 2015 to 2024, the joined layer was copied into two separate layers, using a filter for each one: an incoming layer (net migration rate above 0) and an outgoing layer (net migration rate below 0). Each layer was then shown as a color-coded map, using the same colors for both, red for people leaving, green for people arriving, so the two maps together read as one connected picture. This color-coded approach replaced an earlier plan to use an animated bar chart, since the per-1,000 rate numbers didn't work as well for that as the original headcount numbers from ARDECO did. To ensure that all generated demographic maps are

comparable, the exact same style, legend, and colors were used. Thus, the maps for each decade can be compared with a single swipe on the website. In particular, when looking at all the maps for the decade, in areas where climate stress was indicated as high (4.2) after the last years of 2018-2022, no increase in the number of emigrations was observed within the same year. On the contrary, a significant increase in people leaving is seen in the 2019-2021 maps, 1 to 3 years after the 2018 drought. Similarly, the 2022-2024 maps show no increase after the 2022 drought; in fact, this drought was much more impactful.

The irregularity in this pattern actually constitutes the main finding of the thesis, and it is more accurate to align this with de Haas's (2021) theory rather than calling it a "no-consequence." De Haas's (2021) will-capacity framework anticipates precisely this type of irregular automatic link, indicating that climate stress and migration have this kind of unbalanced connection. This is because moving requires both the desire to move and the actual ability to act on it, and this ability does not manifest in the same way every year and everywhere.

The details regarding COVID-19 should not only be mentioned in chapters 6 and 7, but should also be clearly discussed here. The 2019 to 2021 period, where the delay after 2018 seems to show up, almost completely overlaps with the COVID-19 pandemic. COVID-19 disrupted migration across Europe on its own, both across borders and within countries, because of travel restrictions, lockdowns, and economic shocks that had nothing to do with climate stress. The rise in outgoing migration visible in the 2019–2021 maps therefore cannot be attributed to the 2018 drought with confidence; COVID-19 is a plausible, and possibly larger, contributing factor that cannot be ruled out with the data and methods used in this thesis. The absence of a comparable delayed rise after the larger 2022 shock, in a window largely free of pandemic disruption, is consistent with this interpretation: if the 2019–2021 rise had been a clean climate-driven lag effect, a similar or larger lag would be expected after the more severe 2022 event, and it is not observed.

Restricting the analysis to the 242 urban-type-1 NUTS3 regions actually used in the finished maps (the same boundary set as the Economic Magnet map, §4.3), the clearest 2019–2021 outgoing-migration spike is heavily concentrated in a specific German urban cluster: Heidelberg, Karlsruhe, Stuttgart, Mainz, Frankfurt am Main, Darmstadt, and Cologne, together with smaller centres such as Pforzheim, Landau in der Pfalz, Erlangen, Nuremberg, and Bremen, most of these lying within the same Rhine-Main / Baden-Württemberg corridor. German regions make up 44% of the full urban-type-1 dataset but account for 80% of the thirty regions with the steepest 2019–2021 drops from their pre-2018 baseline, a strong overrepresentation even given Germany's already-large share of the dataset. This is the same broad urban corridor identified in §4.1 as the single densest population cluster (Rhine-Ruhr/Rhine-Main) and, in §4.2, among the regions with the highest concentration of 2018 climate-stress hexagons. This spatial coincidence of population density, climate stress, and delayed outgoing migration is worth noting explicitly. Consistent with the non-causal framing established in Chapter 3, however, it is reported here as a descriptive pattern, not a causal claim.

For the 2022–2024 window, a small minority of regions (22 of 242, roughly 9%) show a 2022–2024 drop at least as steep as their own 2019–2021 drop, a partial exception to the overall pattern of no comparable EU-wide delayed rise after the larger 2022 shock.

Germany again dominates this smaller group (15 of 22), but it also includes Bratislavský kraj, Slovakia, the same region identified in §4.3 as the second-steepest employment-ratio decline (−12.3%) on the Economic Magnet map, making it one of the few individual regions where a weakening "economic magnet" effect and a delayed outgoing-migration signal appear together. This remains a small, partial pattern rather than a systematic second lag equivalent to 2018, and should be read as a minor nuance to the central asymmetry finding rather than a contradiction of it. The clearest post-2018 outgoing-migration spike, visible in the 2019 map, is shown in Figure 16.

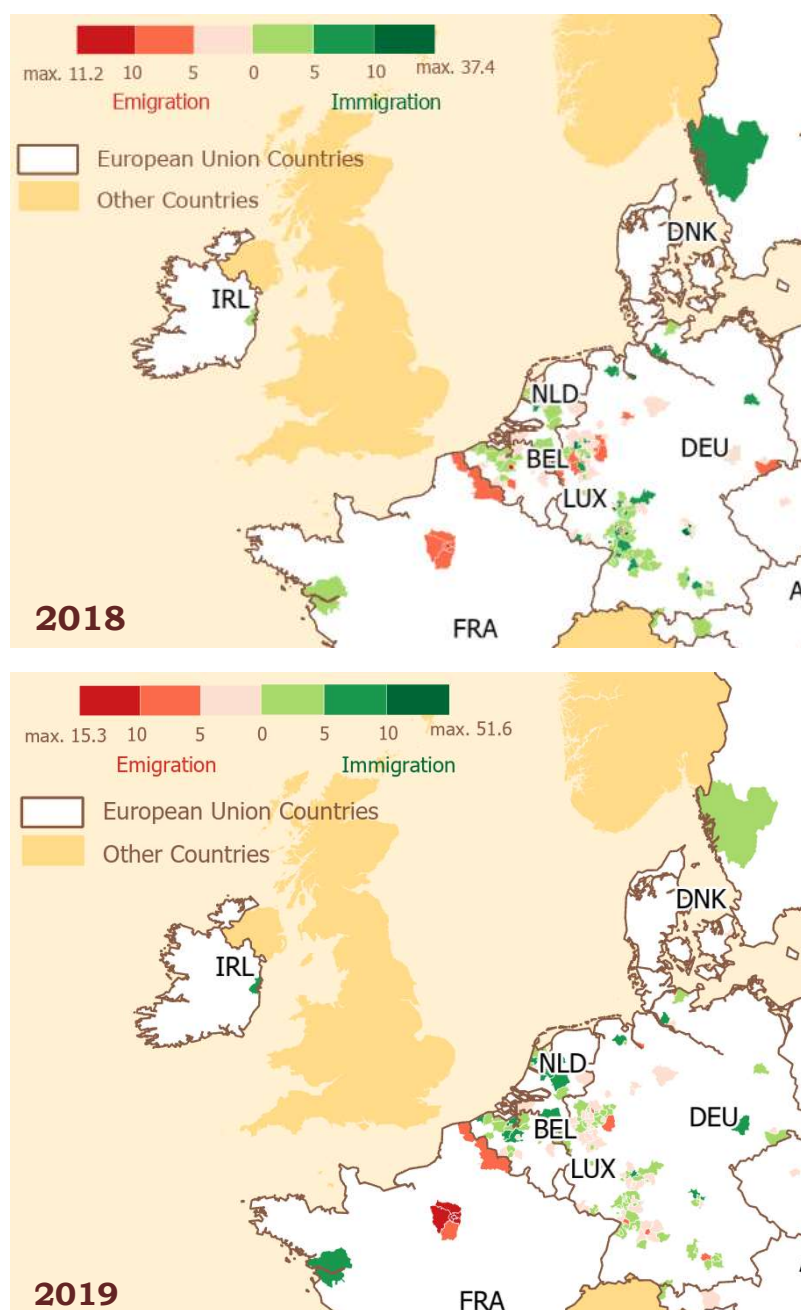


Figure 16 Demographic Heartbeat, 2019: net migration rate across urban NUTS3 regions, with the clearest post-2018 outgoing-migration spike concentrated in the German Rhine-Main/Baden-Württemberg corridor.

4.5 Typology of European Countries (2018 and 2022)

This final pair of Europe maps synthesizes what the three preceding Europe maps each show separately (§4.1–4.4) into two typology maps, one per observed shock year, titled "Typology of European Countries: According to Environmental and Population Dynamics." This replaces an earlier "Future Risk" trajectory concept, whose forward-looking framing the underlying retrospective data could not honestly support.

Used data: The inputs for the Climate Stress Grid (temperature anomaly and NDVI, §4.2), and ARDECO's gross immigration and gross emigration numbers (different from the pre-calculated net migration rate used in §4.4), joined to the NUTS3 boundaries.

Synthetic (typological) mapping, classifying areal units into a small set of descriptive types based on several combined indicators, is a long-established approach in thematic cartography for multivariate regional comparison (Slocum et al., 2009). Each map combines three components into a three-digit classification code per NUTS3 region for the given year. First, a climatic condition score is derived from the same temperature-anomaly and NDVI values behind the Climate Stress Grid (§4.2): each variable is classified into tiers, and the two are combined into a nine-value ordinal score (1 = very friendly, 9 = very harsh), following the same bivariate combination logic as the Climate Stress Grid's own matrix, collapsed here into a single ordinal digit rather than a two-dimensional colour grid. Second and third, ARDECO's gross emigration and gross immigration rates (per 1,000 inhabitants), used here instead of the pre-calculated net migration rate in §4.4, since a typology distinguishing "high inflow with no outflow" from "moderate inflow and moderate outflow" requires the two gross flows separately, are each classified into ordinal tiers, with lower immigration-tier numbers denoting higher inflow.

The three digits (climate, emigration, immigration, in that order) make up each region's code (for example, '930' means climate level 9, emigration level 3, and immigration level 0). These codes were grouped in a way that logically complements each other, creating ten types. These types range from areas with consistent migration flows to areas with no flow, and from areas with low climate stress to areas with the worst climate stress. Furthermore, areas with both the most severe climate stress and the highest migration levels, and where there is no migration to balance it, were associated with a different color to match the design of each platform type (§3.3). The worst-case type, as in the Climate Stress map, was chosen as the most stressful color for the platform, i.e., reddish.

A methodological detail, to avoid confusing the reader, should be explained as follows rather than being ignored: Migration and immigration limits are classified independently for each year, therefore, there is no absolute ratio for the 2018 and 2022 maps, but rather they are determined according to the distribution of that year: the 2018 immigration scale extends to the highest level of "more than 12 percent" in five levels (0-4), while the 2022 scale extends to "more than 10 percent" in four levels (0-3). The climate score's 1–9 scale and its underlying method are held constant across both years. The ten descriptive types themselves are also independently defined per year (worded slightly differently between the two legends, e.g. "regions with high population inflows due to blended economy and

environmental risk" in 2018 versus "climate-stressed regions with immigration due to established urban economies" in 2022), though the underlying code groupings are materially the same type of region in both cases. Both legends were checked to make sure they made sense internally. Each type's codes follow the same pattern across all three digits (for example, every code in a "zero emigration" type has emigration level 0, and code 930, the one worst-case type in both years, correctly combines the harshest climate level, the highest emigration level, and zero immigration). No problems were found. The two typology maps for 2018 and 2022 are shown in Figure 17.

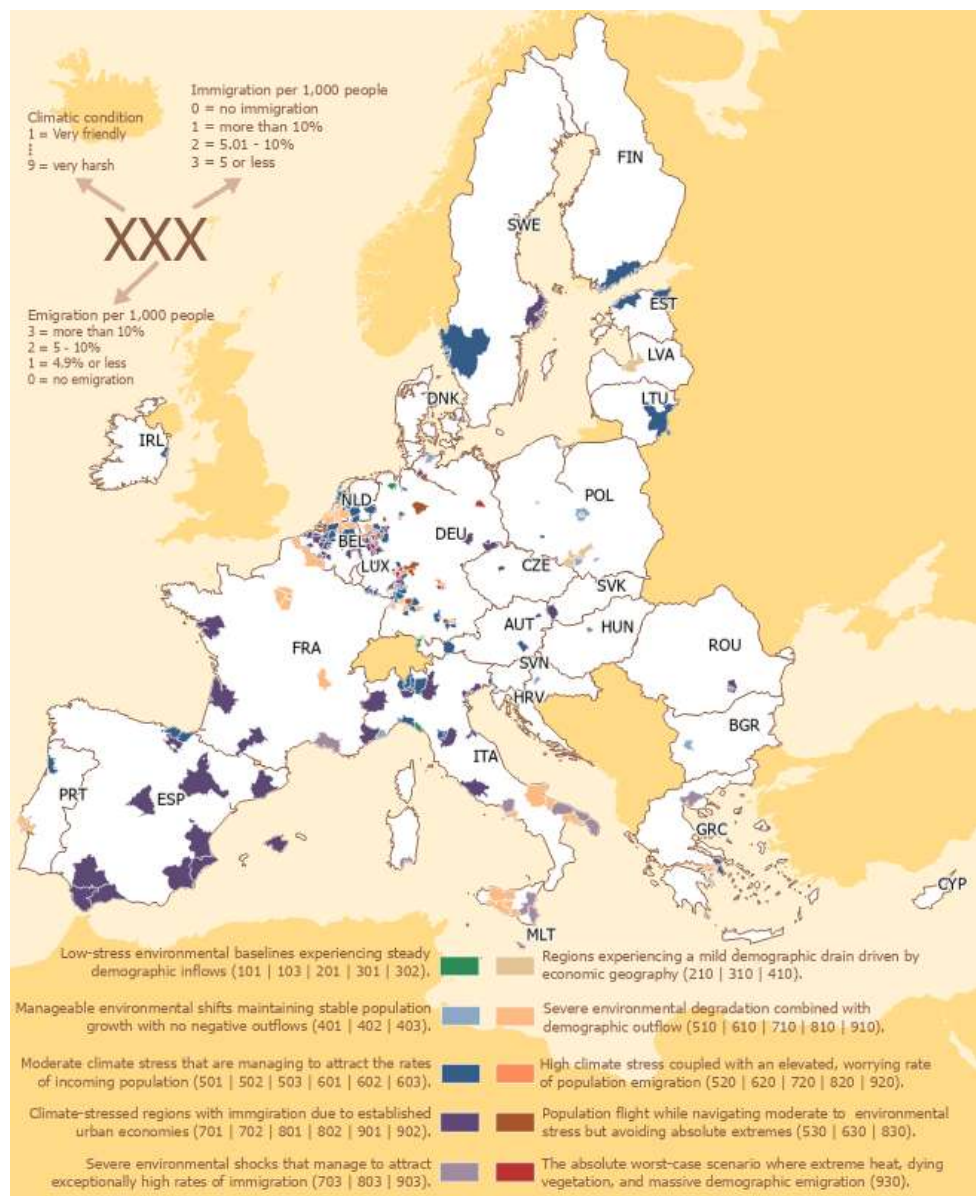


Figure 17 Typology of European Countries, 2018 and 2022: the type combining severe climate stress with continued high immigration and no emigration is the most extensive category in both years, spreading further into France by 2022.

Result: In both years, the type combining severe-to-extreme climate stress with continued high immigration and no emigration (2018: "regions with high population inflows due to blended economy and environmental risk"; 2022: "climate-stressed regions with immigration due to established urban economies") is the most visually extensive category on the map, concentrated heavily across Spain and, to a lesser extent, France. In 2022, this type visibly extends further into central France than it did in 2018. This is consistent with the platform's broader observation that population inflow does not necessarily track climate comfort: regions can remain attractive destinations despite worsening environmental conditions. Southern Italy and Malta fall consistently into the higher-emigration, climate-stressed types in both years, distinct from the Iberian Peninsula, which the Climate Stress Grid (§4.2) identifies as 2022's climate-stress epicentre but which this typology places mostly in the high-inflow rather than high-emigration types, another instance of climate stress and migration outcome not aligning mechanically (§4.4). The worst-case type (930) is rare in both years and, at map scale, visibly present only as a small, isolated patch near the Netherlands–Belgium border in the 2022 map.

5 MALAWI CASE STUDY

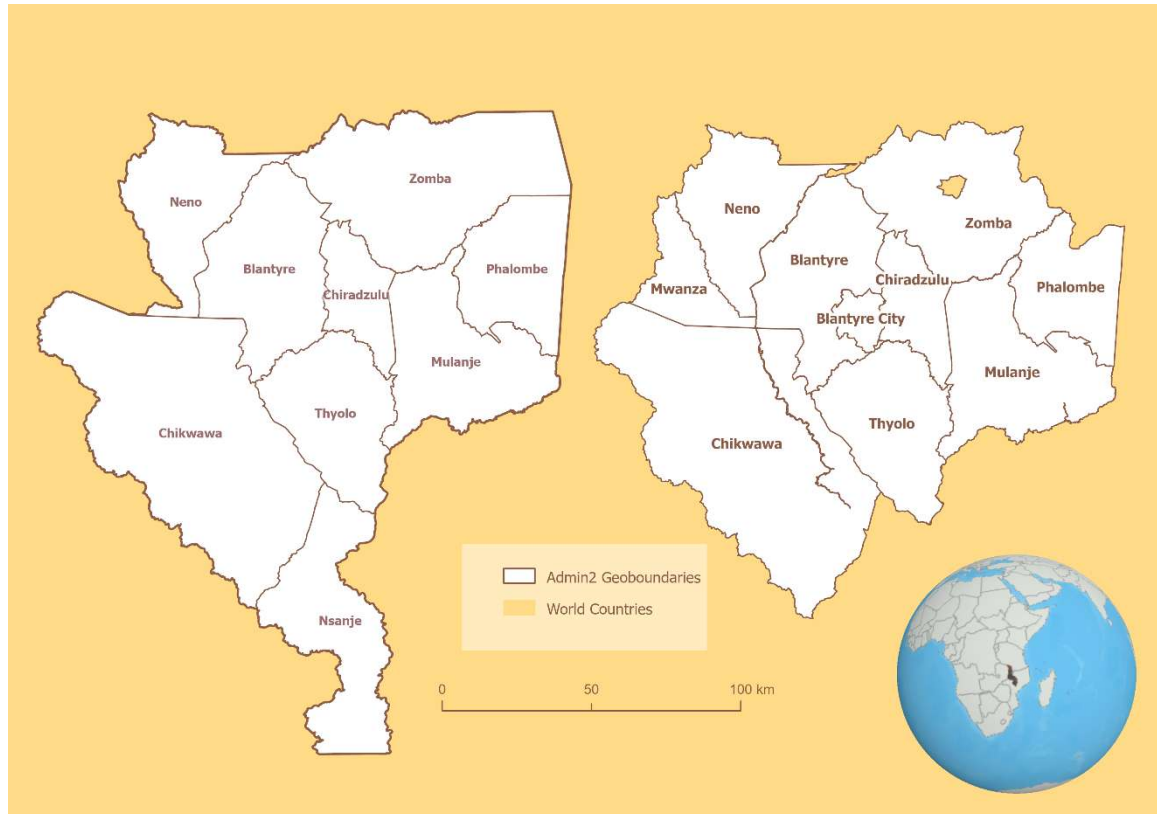


Figure 18 Study area: Southern Malawi districts affected by Tropical Cyclone Freddy (March 2023).

5.1 Displacement Flow

Used Data: This comes from IOM's Displacement Tracking Matrix (DTM) for Malawi, using data from the Multi-Sectoral Location Assessment (MSLA) done after Cyclone Freddy hit, Round 1 (April 2023). For every group of people who moved, the data tells us where they came from, where they went, and how many people were in that group. The majority of the data covers regions in Southern Malawi: Zomba, Blantyre, Nsanje, Chikwawa, and surrounding areas.

A single table containing the starting and ending points is available. Then, using the Create Origin Destination Lines tool, graded lines were created to show the number of people displaced between these points. Following the principle of graduated symbology, flows with more displaced people were shown with thicker lines and a darker color. Subsequently, using the same data, two separate layers were created: the first showing all starting points (origin locations), indicating the locations where people were when the landslide occurred; and the second showing all ending points, indicating the number of people at the camp location after displacement. For both layers, graduated symbols were used in the same way, and larger numbers were represented by larger dots (in thousands), so that this displacement flow map, as the name suggests, shows where people are going

and how many people are going using flowlines. The map shows a total of 190,683 displaced people. It spans 21 starting points and 153 ending points.

These numbers appear to match consistently between the two tiers. This number is the total number derived from the IOM DTM Round 1 dataset. These numbers are based on a systematic camp and settlement-based study and are lower than broader situation report estimates (approximately 362,928 to 659,278 people, per IOM and Malawi Government situation reports). This is not contradictory and is not surprising because the DTM monitors at the settlement level and specifically identifies changes in displaced areas, while national situation report totals focus on a much wider range, including informal arrangements and areas outside the scope of the DTM. Although the two figures are quite contradictory, their methodological scopes differ, so when quoting them, the source and methodology of both should be clearly stated; otherwise, the DTM total figures may lead to a misinterpretation of the scale of the disaster.

The highest number of outgoing people were concentrated in the south of the cyclone-directly affected area, where the risk of flooding was highest: Ngabu (50,721 displaced people, Chikwawa region), Makhwira (41,592, Chikwawa), Malemia (22,994, near Blantyre), Tengani (16,503, Nsanje region), and Lundu (9,427, Chikwawa). These five cities alone account for 74% of the total displacement shown on the map. Displacement from each major source was not concentrated in a single destination point but was distributed across many different locations. For example, flows from Makhwira were distributed to 13 different destination points, while those from Ngabu were distributed to 17. Looking at the destination points, it is seen that the sources are more tightly clustered than the origin points, and are particularly concentrated around Blantyre. This situation is consistent with the city's role as an urban attraction factor even in the event of a sudden disaster and displacement (see Objectives, dual-case framing). The largest individual destinations are Nyangu School (11,999 people received), Sekeni Camp (8,420), Kapalakonje camp (7,543), Jombo School Camp (6,230), and Savala Evacuation Centre (5,980), considerably smaller individually than the largest origins, reflecting this dispersal pattern rather than a small number of dominant reception sites. The convergence of destinations around Blantyre is shown in Figure 19.

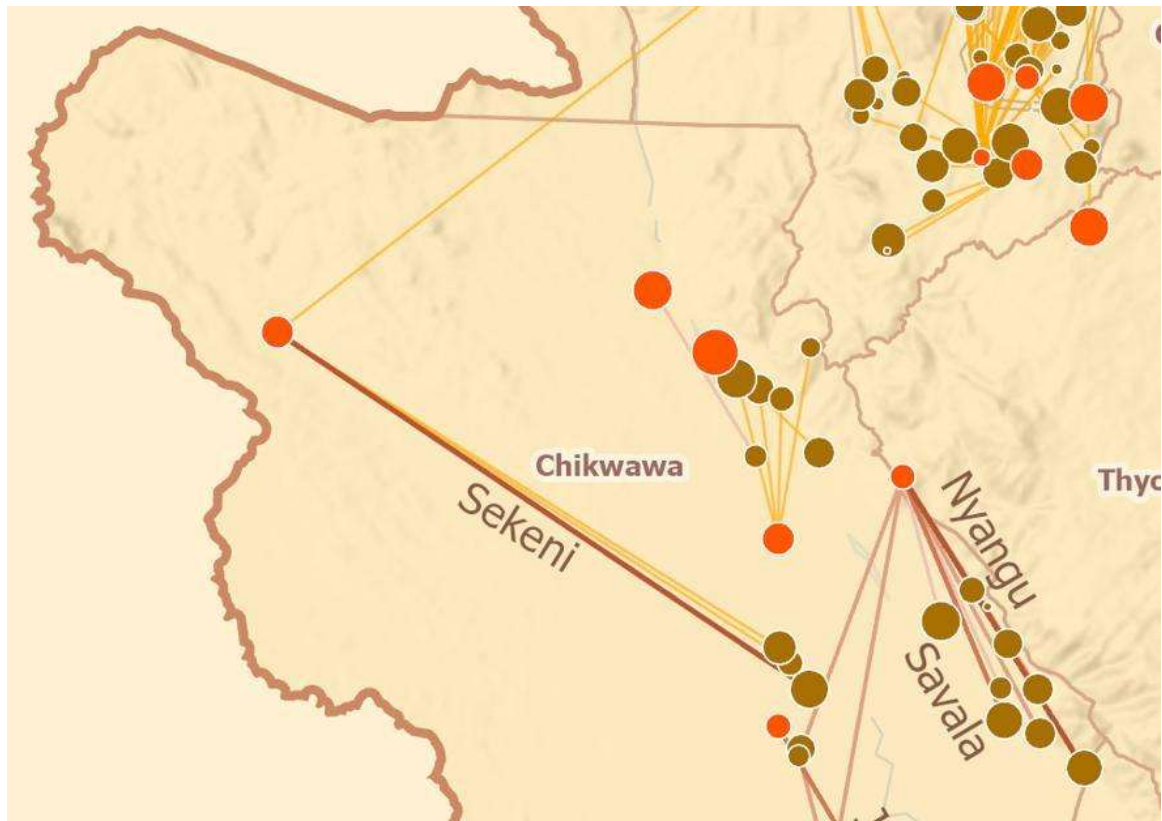


Figure 19 Displacement Flow, detail around Blantyre: destinations cluster tightly around the city despite origins being dispersed across the wider region.

5.2 Bivariate Susceptibility

Used Data: Population raster layers for 2020 and 2025 (from OCHA's Humanitarian Data Exchange, §3.1.5), OCHA's Admin3 administrative boundaries for Malawi, and a landslide layer that was digitized by hand using before-and-after Sentinel-2 and Planet satellite images (§3.1.6).

A map of landslide locations for Southern Malawi was not easily available and had to be made from scratch for this thesis. Sentinel-2 images, along with extra Planet images, taken just before and after Tropical Cyclone Freddy (March 2023) were compared by eye across the ten districts in the study area. More than a thousand individual shapes were then drawn by hand in ArcGIS Pro, marking areas that clearly showed landslide damage such as bare soil, cracks in the land, and missing vegetation that appeared in the "after" image but weren't in the "before" image. This polygon layer forms the source features for the landslide-exposure variable described below, representing documented Cyclone Freddy landslide occurrence rather than a predictive susceptibility model or a third-party hazard dataset. Absolute population shift was calculated using the Raster Calculator, subtracting the 2020 population raster from the 2025 population raster to produce a single layer representing net population change over the five-year window. A landslide threat layer was generated using Euclidean Distance run against the digitized landslide polygons, producing a continuous surface representing proximity to documented landslide occurrence. Zonal Statistics was used twice: once to extract mean population shift into each Admin3 district, and once to extract mean landslide-proximity value into

the same districts. Both summary tables were joined to the Admin3 boundary layer. An expert review and validation check (see Chapter 3) subsequently found that the raw Euclidean Distance output increases with distance from landslide-affected terrain rather than with proximity to it; the exposure field was inverted before classification so that districts closest to documented landslide occurrence are correctly represented as most exposed. A bivariate symbology was then applied, combining population shift and the corrected landslide-exposure field into a single colour matrix, following the same bivariate logic used for the Climate Stress Grid in the Europe case (Chapter 4), so that districts combining large population change with high landslide exposure are visually distinguished from districts where only one factor is elevated.

Result: In total, 24 of the 119 Admin3 units are in the "both high" category, meaning they are in the highest-risk third, carrying both landslide risk and population growth risk. 23 of these 24 units are neighbourhoods in the city of Blantyre, mostly in Ndirande (Makata, Gamulani, and Matope neighbourhoods), Bangwe, Mbayani, Soche West, Chilomoni, and South Lunzu. These areas are among the informal settlements that have been featured in international news and identified as the primary source of landslide deaths in 2023. In terms of proximity to the city of Blantyre, Chiradzulu Boma is the only Admin3 unit located just outside Blantyre that also has the highest landslide risk. On the other hand, Phalombe Boma is the only unit outside Blantyre that has "both high" risk. Although rural Zomba (the lowest areas furthest from the hilly terrain associated with cyclone landslides), Chikwawa, Mwanza, and Neno consistently fall into the low-risk category, the Mulanje and Thyolo areas mentioned in the map's subtitle only have a moderate landslide risk. This situation also affects and modifies how the previous finding should be interpreted. Population pressure and landslide risk actually overlap in one specific place, Blantyre City's informal hillside neighborhoods, rather than across the wider Blantyre–Mulanje area that the map's title seems to suggest. Figure 20 shows this concentration over Blantyre City.

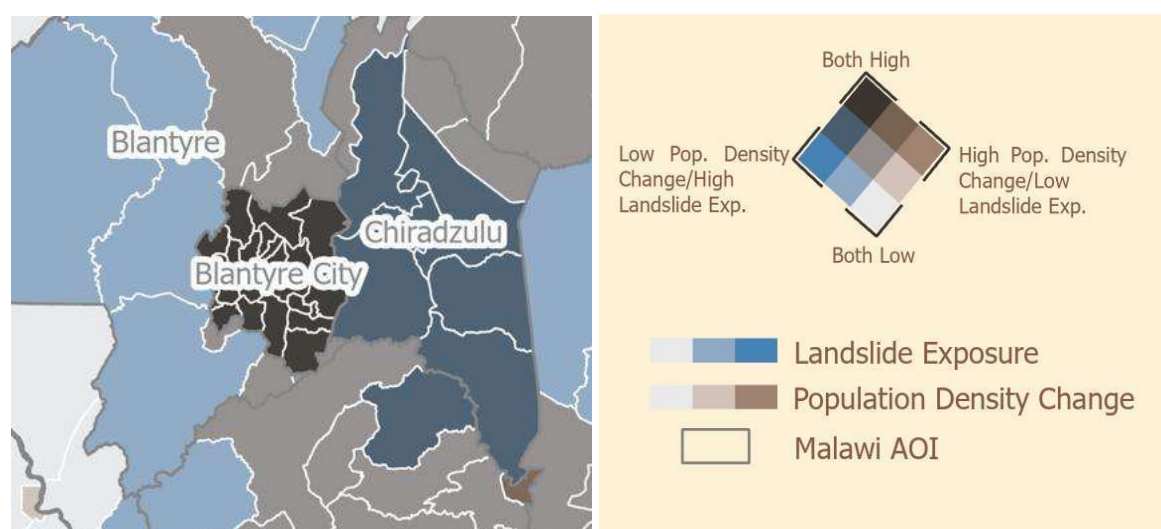


Figure 20 Bivariate Susceptibility, detail over Blantyre City: the darkest cluster concentrates in the same informal hillside wards documented as the epicentre of the March 2023 landslide deaths.

6 RESULTS

The platform comprises 18 map outputs across the two case studies: 16 in the Europe slow-onset panel (Human Canvas, two Climate Stress Grid maps, Economic Magnet, ten annual Demographic Heartbeat maps, and the two Typology of European Countries maps) and two in the Malawi rapid-onset case (Displacement Flow and Bivariate Susceptibility). Results are summarized below by case, in the sequence established in Chapters 4 and 5, which report the full processing detail and findings behind each map; this chapter synthesizes only the outcomes.

Read across the ten-year Demographic Heartbeat sequence, outgoing migration does not rise in the same year as either the 2018 or the 2022 drought shock identified in the Climate Stress Grid (§4.2). A delayed rise appears only in 2019–2021, concentrated in a German Rhine-Main/Baden-Württemberg cluster of regions (§4.4), but this window coincides with the COVID-19 pandemic and cannot be attributed to climate stress with confidence. No comparable delayed rise follows the larger 2022 shock, and Economic Magnet employment-ratio change (§4.3) does not spatially correspond to the climate-stress hexagons either. This asymmetric, non-mechanical pattern is consistent with de Haas's (2021) aspirations-capabilities framework rather than a null result. The Typology of European Countries pair (§4.5) reinforces this same disconnect from a different angle: in both 2018 and 2022, the type combining severe climate stress with continued high immigration and no emigration is the most extensive category on the map, concentrated in Spain and, increasingly by 2022, France; these regions remain attractive destinations even as their climatic condition worsens, rather than the two moving together.

The Displacement Flow Map (§5.1) generated for the Malawi case clearly shows that destinations are disproportionately clustered around Blantyre, and that large-volume origins are also concentrated in high-risk flood areas affected by Cyclone Freddy. The city plays a role as a pull factor even in this atypical rapid-onset event. The Bivariate Susceptibility map (§5.2), once its landslide-exposure axis was corrected during validation (Chapter 3), shows demographic pressure and landslide risk co-occurring almost exclusively within Blantyre City's informal hillside wards (Ndirande, South Lunzu, Chilimoni, Soche West, Bangwe, Mbayani), rather than distributed evenly across the wider Blantyre–Mulanje region named in the map's title.

Read together, the two cases show that urban environments do not relate to climate-induced migration in a single way. In Europe, cities function predominantly as destinations: the majority of urban regions show net inflow across most of the 2015–2024 sequence (§4.4). The clearest deviation from that baseline, the delayed 2019–2021 outgoing-migration spike in German urban regions, is confounded with the COVID-19 pandemic rather than cleanly attributable to climate stress. In Malawi, the city is epicenter and destination at once: Blantyre is struck directly by the cyclone, yet remains the strongest pull factor for population displaced from surrounding districts, and its own population growth continues to concentrate in precisely the hillside wards most exposed to landslides during the recovery period. The key cross-case finding is that the urban experience of climate-induced migration occurs in at least two structurally different ways, depending on whether the city is located downstream or within the footprint of the climate event.

No statistical or cause-and-effect test was done on either pattern. Both are just described, in the same way Chapter 3 explained things should be shown, without claiming one thing causes another. The two cases also aren't meant to be compared using statistics, since

they cover different time spans and use different spatial units. Chapter 7 (Discussion) looks more closely at these findings, as well as the platform's limitations.

User Testing Results: The platform was evaluated through the small-scale, indicative usability and comprehension check described in §3.9. Six participants completed the survey. The intended primary audience, a practicing urban planner, could not be recruited within the project timeline, so the achieved sample comprised three participants with a geoinformatics or GIS background, two from other academic fields, and one from outside academia; the planning perspective the study set out to include is therefore absent, and this is stated plainly rather than glossed over. Consistent with §3.9, the results are read as an indicative check on whether the platform communicates its intended findings, not as a statistically representative evaluation; with a convenience sample of this size, and without the target planning audience, they are treated qualitatively rather than as generalisable measures.

On the task-based comprehension questions, which asked each participant to read one specific finding directly off a named map, four of the six participants correctly identified the 2022 shift of climate stress toward Iberia and France on the Climate Stress Grid; four of six identified the delayed 2019 to 2021 outgoing-migration window on the Demographic Heartbeat series; and four of six identified the Blantyre destination cluster on the Displacement Flow map. The three map findings were therefore communicated at the same rate, to a clear majority but not to every reader, with the two misreadings in each case spread across the alternative options rather than concentrated on a single competing answer.

The non-causal framing check (§3.8) is reported separately, as the single most important communication outcome, and it is also the weakest result. Only three of the six participants understood the platform as presenting the climate-stress and migration patterns side by side for the reader to compare; two read it as claiming that climate stress causes the migration shown, and one was unsure. That half the sample did not receive the descriptive, non-causal framing as intended is recorded here honestly as a limitation of the current design rather than a success: the visual juxtaposition of stress and migration maps carries a real risk of being read causally, exactly the reviewer criticism anticipated in §3.8, and strengthening the explicit framing in the map captions and section text is identified as a priority improvement (Chapter 7).

On the design ratings (five-point Likert, reported as medians given the ordinal data and small sample), participants rated the clarity of the map colours and legends at a median of 5 (range 3 to 5), the coherence of the Europe and Malawi maps as one platform at a median of 4.5 (range 4 to 5), and overall trust in the platform for a real planning or policy discussion at a median of 4 (range 3 to 5), with full response distributions given in the Attachments. Throughout the survey, the descriptions and carefully chosen colors listed for each map received the highest score for clarity and the lowest score for reliability... However, all three median values are at the positive end of the scale. The coherence rating specifically tests the §3.3 design-system claim that the suite reads as one platform despite its deliberate Europe and Malawi register shift; the observed median of 4.5, with no response below 4, supports that claim for this sample.

Before user testing, comparing maps and identifying a specific theme was challenging. Open-ended feedback brought this to a consistent and implementable level. Two participants specifically asked for the two years to be overlaid with a swipe to compare rather than shown side by side, and one added that the maps should be legible without opening each one individually, the Malawi maps in particular. This point was acted on before submission: the two year-pair comparisons (Climate Stress Grid and Typology) were rebuilt as an overlay swipe-to-compare on the story page, directly implementing the change participants requested. Other comments included one non-specialist reader feeling initially overwhelmed by the amount of information and not noticing the charts embedded alongside the maps, a suggestion to highlight the Rhine-Ruhr population cluster more distinctly, a note that part of the testing was carried out on a mobile phone, and a suggestion to add a narrated video walkthrough; one participant reported nothing confusing. These remaining points are recorded as future improvements in Chapter 7.

Overall, the check indicates that the platform communicated each of its three core map findings to a majority of participants and was rated highly for clarity and cross-case coherence, but that its descriptive, non-causal framing reached only half the sample and is the clearest communicative weakness, alongside the side-by-side map comparison that testing prompted an immediate redesign of. These results remain, as framed in §3.9, an indicative usability signal from a small convenience sample without the target planning audience, rather than a representative evaluation.

7 DISCUSSION

The mismatch between climate stress and migration is not a failed result. In fact, it supports de Haas's aspirations-capabilities framework, and it shows why careful design of the visuals is needed, so people do not get the wrong idea about cause and effect.

The years with climate shocks (2018 and 2022) do not show an immediate rise in people leaving that same year. A delayed rise does appear one to three years after the 2018 shock (2019–2021), but this time period overlaps with COVID-19, which also disrupted migration on its own, so COVID cannot be ruled out as a factor either. After the 2022 shock (2022–2024), there's no similar delayed rise. This suggests that even if climate and migration are linked, the delay isn't always the same fixed length of time. This fits with de Haas's (2021) framework: even when a delayed response seems likely, it doesn't happen automatically, and it doesn't happen the same way every time. The 2019–2021 period, used to look at the "lag" after 2018, almost completely overlaps with the COVID-19 pandemic. So, the main reason for the delay we're seeing might not be solely climate stress, but also disruptions caused by the pandemic.

Cities play very different roles depending on their location; for example, cities in Europe are very conducive to attracting people, and when we look at a 10-year timeline, far more people arrive than leave, but in Malawi, the situation is very different. Cities are heavily affected by landslides, but when people want to leave their homes, they still go to these places. Therefore, when we evaluate migration in relation to climate and cities, we can conclude that there is no single pattern. There are at least two. It depends on whether the city is somewhere downstream from the climate event, or right in its path. This finding supports the idea, already introduced in the Objectives and State of Art, that there are two different speeds or types of climate impact.

Any platform visualizing climate stress and migration together risks readers misreading visual juxtaposition as causation; this thesis's own data demonstrates that risk is real even in extreme shock years, reinforcing the need for explicit narrative framing, following Segel and Heer, as a genuine safeguard.

For policymakers, the platform allows identification of areas of obvious climate-driven crisis to inform resource allocation decisions. For city planners, it allows anticipation of housing and service pressure from incoming migration, and prioritization of resilient rebuilding.

The limits of this work are stated honestly. No statistical or causal testing was done, both as a deliberate choice in how the work was carried out, and as a real limitation. It is not possible to say that the delay after 2018 is solely due to climate stress because the COVID-19 factor must be taken into account at this point. Also, the data came from different sources in quite different formats, and expert review was only used in six point checks. Three of these checks found some errors that needed correction (Section 3). These two case studies differ in many ways, especially structurally. Malawi uses only the Admin3 monitoring method, while Europe uses the NUTS3 panel. This thesis does not aim to statistically compare the two. The conclusion in §4.5 is explained with words and

visuals because precise numbers were not available for each region. This is already stated as a limitation specific to that section.

Regarding future studies, geographical expansion beyond Europe to regions such as the Pacific Islands, the Sahel, or South Asia, and legitimate follow-up research such as statistical analyses based on causal panel analysis or an econometric framework, as explicitly stated in the Methodology section, are included.

User testing (Chapter 6) incorporates many tangible improvements. The most important is strengthening the explicit non-causal framing, since only half the participants read the side-by-side maps as descriptive rather than causal; clearer caption and section wording stating that the maps are compared, not causally linked, is the priority change. Testing also prompted one improvement that was already implemented before submission, rebuilding the paired before-and-after maps as an overlay swipe-to-compare, and identified several others for future work: making the maps legible at full size without opening each one individually (the Malawi maps in particular), reducing the visual dominance of the warm background tones so the embedded charts are noticed, improving the mobile layout, and highlighting key clusters such as Rhine-Ruhr more distinctly. A narrated video walkthrough of the maps was also suggested as a complementary way to reach non-specialist audiences.

8 CONCLUSION

This thesis contributes a geovisual storytelling platform that works at a sub-national level and covers two different speeds of change (slow-onset and rapid-onset). It is built using more than ten different ArcGIS Pro mapping techniques, and it shows where climate stress and migration or displacement patterns do and do not line up. It is made for planning and policy audiences, and it does not claim that climate stress causes migration. Interpreted geographically, the two cases show clearly different patterns of alignment. In Europe, climate stress and migration largely do not line up in space or time. The regions that suffered the most severe stress in 2022, the Iberian Peninsula and France, continued to attract incoming migration rather than lose population, and no region showed an immediate rise in outgoing migration in a drought year. The one partial exception is the German Rhine-Main and Baden-Württemberg corridor, where a delayed rise in outgoing migration in 2019 to 2021 coincides spatially with both high population density and the 2018 stress concentration; even here, the timing overlaps with the COVID-19 pandemic, so the apparent alignment cannot be attributed to climate stress with confidence. In Malawi, by contrast, climate stress and displacement line up strongly and locally. The largest displacement origins fall in the flood-prone southern districts of Chikwawa and Nsanje that Tropical Cyclone Freddy struck directly, the displaced population converges on Blantyre, and the combination of high population pressure and landslide exposure concentrates almost entirely in Blantyre City's informal hillside wards, such as Ndirande, South Lunzu, Chilomoni, and Soche West. The central geographical conclusion is therefore that alignment between climate stress and migration depends on the type of event: it is weak, delayed, and spatially diffuse under slow-onset drought in Europe, but strong, immediate, and spatially concentrated under the rapid-onset cyclone in Malawi.

This thesis can be distinguished from previous research in three major design aspects: firstly, it has a completely different style compared to the IOM's Climate Mobility Impacts Dashboard because it is not a dashboard, but a storytelling platform; secondly, it is visually much richer because it combines many mapping techniques with a large number of graphic techniques.

The link between climate stress and migration is real, but it does not happen automatically. Seeing this across many different, carefully chosen types of maps makes this complexity visible in a way that text or numbers alone cannot. This thesis gives a real, working example of how to show a climate-migration relationship in a responsible way, without suggesting a false cause-and-effect link, across two very different contexts at the same time.

REFERENCES AND INFORMATION SOURCES

- Andrienko, G., Andrienko, N., & Savinov, A. (2001). Choropleth maps: Classification revisited. In *Proceedings of the 20th International Cartographic Conference (ICC)* (pp. 1209–1219). Beijing, China.
- Baggio, L., Bucciarelli, G., Bussolari, I., & Dijkstra, L. (2024). *The Annual Regional Database of the European Commission (ARDECO) – Methodological note* (JRC138212). European Commission, Joint Research Centre.
- Bertin, J. (2010). *Semiology of graphics: Diagrams, networks, maps* (W. J. Berg, Trans.). Esri Press. (Original work published 1967)
- Buras, A., Rammig, A., & Zang, C. S. (2020). Quantifying impacts of the drought 2018 on European ecosystems in comparison to 2003. *Frontiers in Plant Science*, 11, Article 298. <https://doi.org/10.3389/fpls.2020.00298>
- Choler, P. (2023). Above-treeline ecosystems facing drought: Lessons from the 2022 European summer heat wave. *Biogeosciences*, 20, 4259–4272. <https://doi.org/10.5194/bg-20-4259-2023>
- Cissé, G., McLeman, R., Adams, H., Aldunce, P., Bowen, K., Campbell-Lendrum, D., Clayton, S., Ebi, K. L., Hess, J., Huang, C., Liu, Q., McGregor, G., Semenza, J., & Tirado, M. C. (2022). Health, wellbeing, and the changing structure of communities. In *Climate change 2022: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press. <https://doi.org/10.1017/9781009325844.009>
- de Haas, H. (2021). A theory of migration: The aspirations-capabilities framework. *Comparative Migration Studies*, 9, Article 8. <https://doi.org/10.1186/s40878-020-00210-4>
- Dijkstra, L., Poelman, H., & Veneri, P. (2019). *The EU-OECD definition of a functional urban area* (OECD Regional Development Working Papers No. 2019/11). OECD Publishing. <https://doi.org/10.1787/d58cb34d-en>
- Dodman, D., Hayward, B., Pelling, M., Castan Broto, V., Chow, W., Chu, E., Dawson, R., Khirfan, L., McPhearson, T., Prakash, A., Zheng, Y., & Ziervogel, G. (2022). Cities, settlements and key infrastructure. In *Climate change 2022: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 907–1040). Cambridge University Press. <https://doi.org/10.1017/9781009325844.008>
- Drusch, M., Del Bello, U., Carlier, S., Colin, O., Fernandez, V., Gascon, F., et al. (2012). Sentinel-2: ESA's optical high-resolution mission for GMES operational services. *Remote Sensing of Environment*, 120, 25–36. <https://doi.org/10.1016/j.rse.2011.11.026>

- Eurostat. (n.d.). *NUTS – Nomenclature of territorial units for statistics: Overview*. European Commission. Retrieved July 12, 2026, from <https://ec.europa.eu/eurostat/web/nuts/>
- Florczyk, A. J., Corbane, C., Ehrlich, D., Freire, S., Kemper, T., Maffenini, L., Melchiorri, M., Pesaresi, M., Politis, P., Schiavina, M., Sabo, F., & Zanchetta, L. (2019). *GHS data package 2019* (EUR 29788 EN). Publications Office of the European Union. <https://doi.org/10.2760/290498>
- Garrison, M. (2021). *Transportation, emotion, and climate change attitude: Understanding map reader response to storytelling maps* [Master's thesis, University of Oregon]. Scholars' Bank. <https://scholarsbank.uoregon.edu/xmlui/handle/1794/26728>
- Guo, D., & Zhu, X. (2014). Origin-destination flow data smoothing and mapping. *IEEE Transactions on Visualization and Computer Graphics*, 20(12), 2043–2052. <https://doi.org/10.1109/TVCG.2014.2346271>
- Hersbach, H., et al. (2020). The ERA5 global reanalysis. *Quarterly Journal of the Royal Meteorological Society*, 146(730), 1999–2049. <https://doi.org/10.1002/qj.3803>
- International Organization for Migration. (n.d.). *Methodological framework used in DTM operations for quantifying displacement and mobility*. Displacement Tracking Matrix. Retrieved July 12, 2026, from <https://dtm.iom.int/about/methodological-framework>
- International Organization for Migration, Global Data Institute. (2023). *Climate mobility impacts dashboard*. Migration Data Portal. Retrieved July 12, 2026, from <https://www.migrationdataportal.org/climate-mobility-impacts>
- Muñoz-Sabater, J., et al. (2021). ERA5-Land: A state-of-the-art global reanalysis dataset for land applications. *Earth System Science Data*, 13(9), 4349–4383. <https://doi.org/10.5194/essd-13-4349-2021>
- Planet Team. (2023). *Planet application program interface: In space for life on Earth*. Planet Labs PBC. Retrieved July 13, 2026, from <https://api.planet.com>
- Possega, M., García-Valdecasas Ojeda, M., & Gámiz-Fortis, S. R. (2023). Multi-scale analysis of agricultural drought propagation on the Iberian Peninsula using non-parametric indices. *Water*, 15(11), Article 2032. <https://doi.org/10.3390/w15112032>
- Segel, E., & Heer, J. (2010). Narrative visualization: Telling stories with data. *IEEE Transactions on Visualization and Computer Graphics*, 16(6), 1139–1148. <https://doi.org/10.1109/TVCG.2010.179>
- Slocum, T. A., McMaster, R. B., Kessler, F. C., & Howard, H. H. (2009). *Thematic cartography and geovisualization* (3rd ed.). Pearson.
- Toffano, G., & Smets, K. (2021). Migration Trail: Exploring the interplay between data visualisation, cartography and fiction. In M. Sandberg, L. Rossi, V. Galis, & M. B. Jørgensen (Eds.), *Research methodologies and ethical challenges in digital*

migration studies: Caring for (big) data? (pp. 87–112). Springer.
https://doi.org/10.1007/978-3-030-81226-3_4

Toreti, A., Bavera, D., Acosta Navarro, J., Cammalleri, C., de Jager, A., Di Cesare, L., Hrašt Essenfelder, A., Maetens, W., Magni, D., Masante, D., Mazzeschi, M., Niemeyer, S., & Spinoni, J. (2022). *Drought in Europe August 2022* (JRC130493). Publications Office of the European Union.
<https://doi.org/10.2760/264241>

Trumbo, B. E. (1981). A theory for coloring bivariate statistical maps. *The American Statistician*, 35(4), 220–226. <https://doi.org/10.1080/00031305.1981.10479360>

Tucker, C. J. (1979). Red and photographic infrared linear combinations for monitoring vegetation. *Remote Sensing of Environment*, 8(2), 127–150.
[https://doi.org/10.1016/0034-4257\(79\)90013-0](https://doi.org/10.1016/0034-4257(79)90013-0)

LIST OF ATTACHMENTS

Attachments 1–18 correspond directly to the appendix number stamped on each map layout itself, in the order the maps are introduced across Chapters 4 and 5, so that a reader can match a printed map to its listing here without ambiguity.

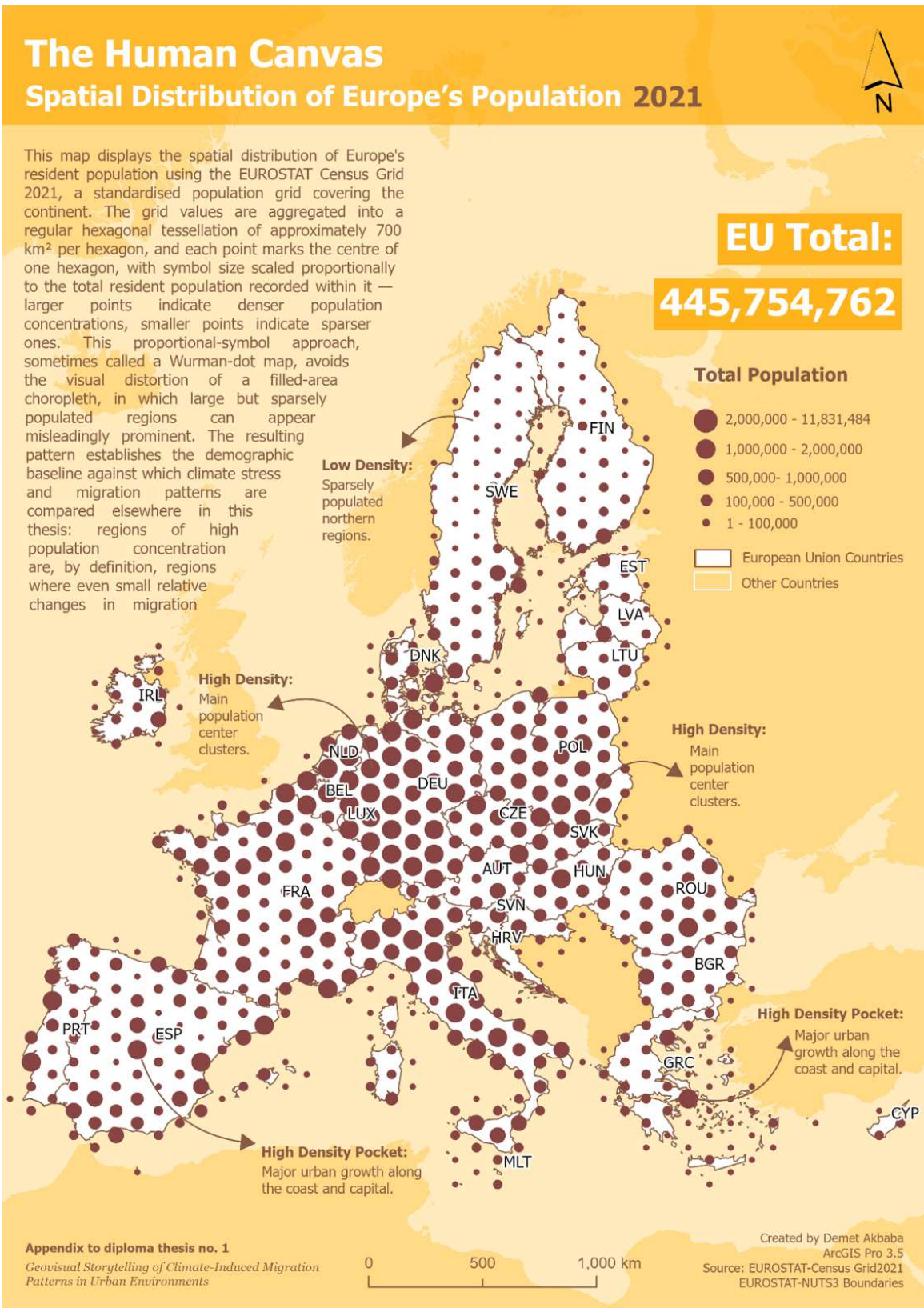
Bound attachments:	
Attachment 1	Human Canvas (Wurman Dots)
Attachment 2	Climate Stress Grid 2018
Attachment 3	Climate Stress Grid 2022
Attachment 4	Economic Magnet
Attachment 5	Demographic Heartbeat 2015
Attachment 6	Demographic Heartbeat 2016
Attachment 7	Demographic Heartbeat 2017
Attachment 8	Demographic Heartbeat 2018
Attachment 9	Demographic Heartbeat 2019
Attachment 10	Demographic Heartbeat 2020
Attachment 11	Demographic Heartbeat 2021
Attachment 12	Demographic Heartbeat 2022
Attachment 13	Demographic Heartbeat 2023
Attachment 14	Demographic Heartbeat 2024
Attachment 15	Typology of European Countries 2018

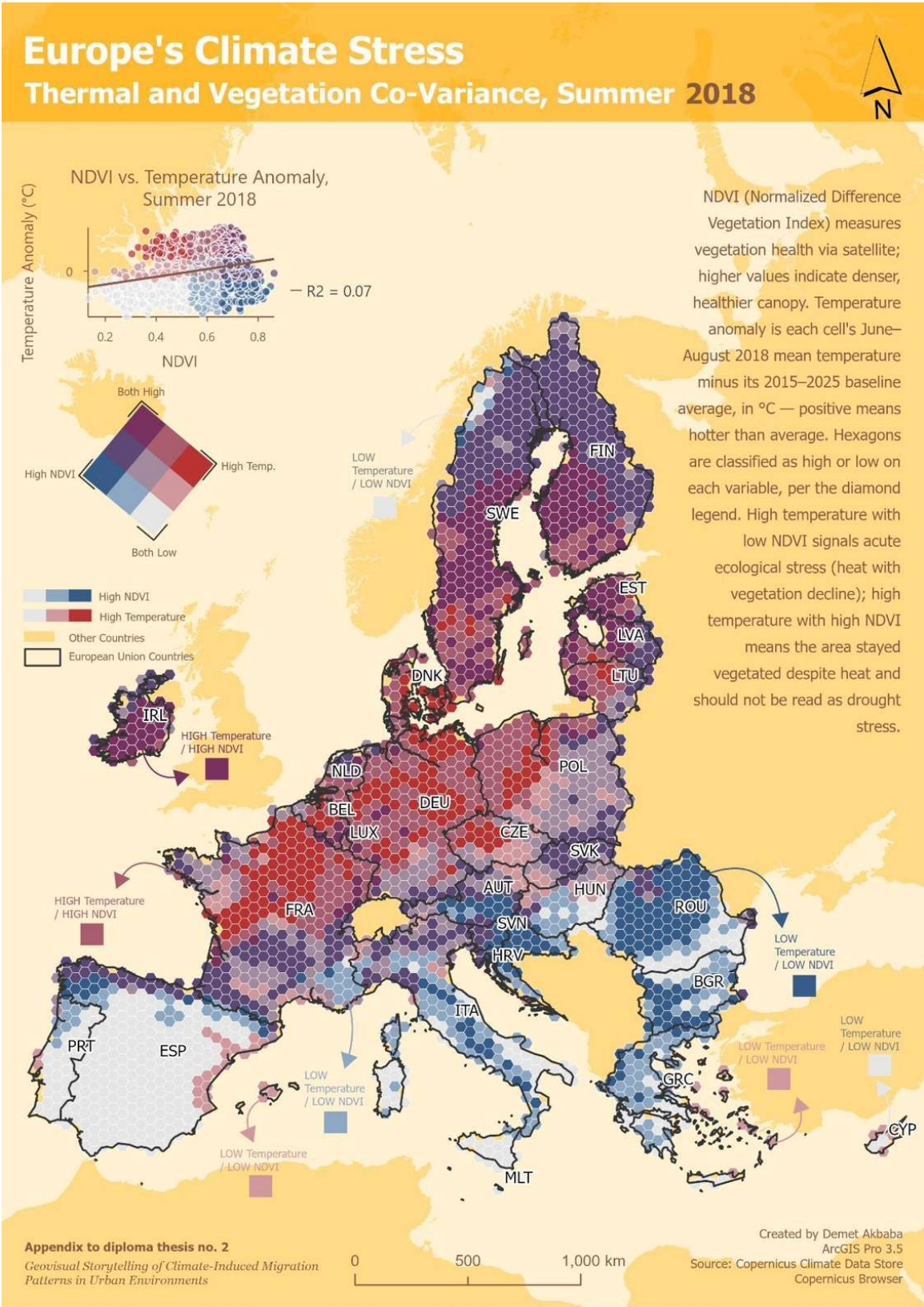
Attachment 16	Typology of European Countries 2022
Attachment 17	Displacement Flow (Malawi)
Attachment 18	Bivariate Susceptibility (Malawi)
Attachment 19	User Testing Questionnaire and Responses
Free attachments:	
Attachment 20	Thesis Poster (Printed A2 Format)
Attachment 21	Digital Data (Zip Folder)

Structure of Attachment 21

Folder	Sub-Folder	Files
Digital Data	Text	Final thesis (PDF), annotation
	Input Data	Copernicus climate rasters, migration and population tables, boundary layers
	Output Maps	The 18 map layouts (PDF + full-resolution PNG)
	Thesis Data	ArcGIS Pro projects (APRX), geodatabases
	Web	Website files (HTML, CSS, images)
	Poster	A2 poster (print-ready PDF)

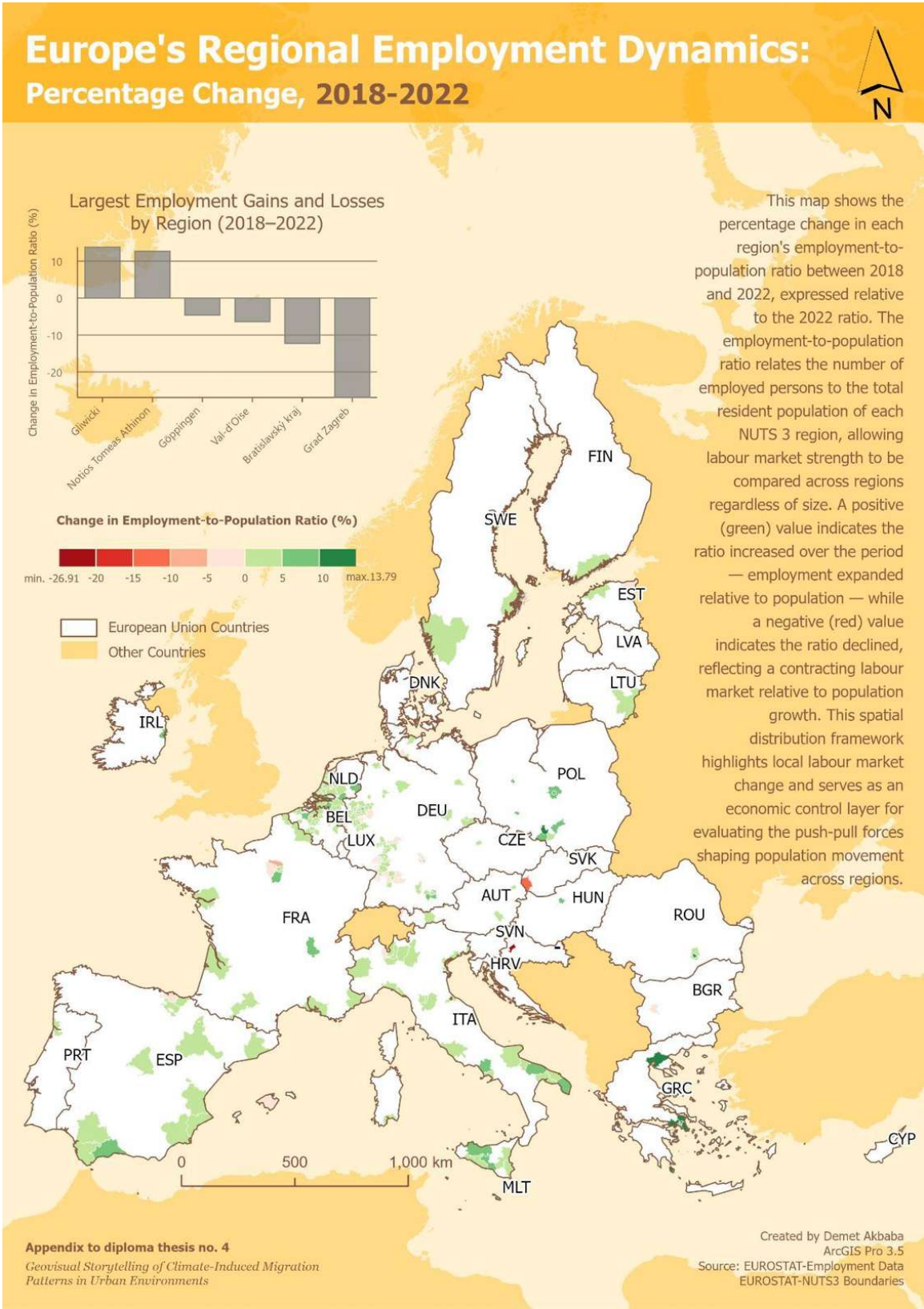
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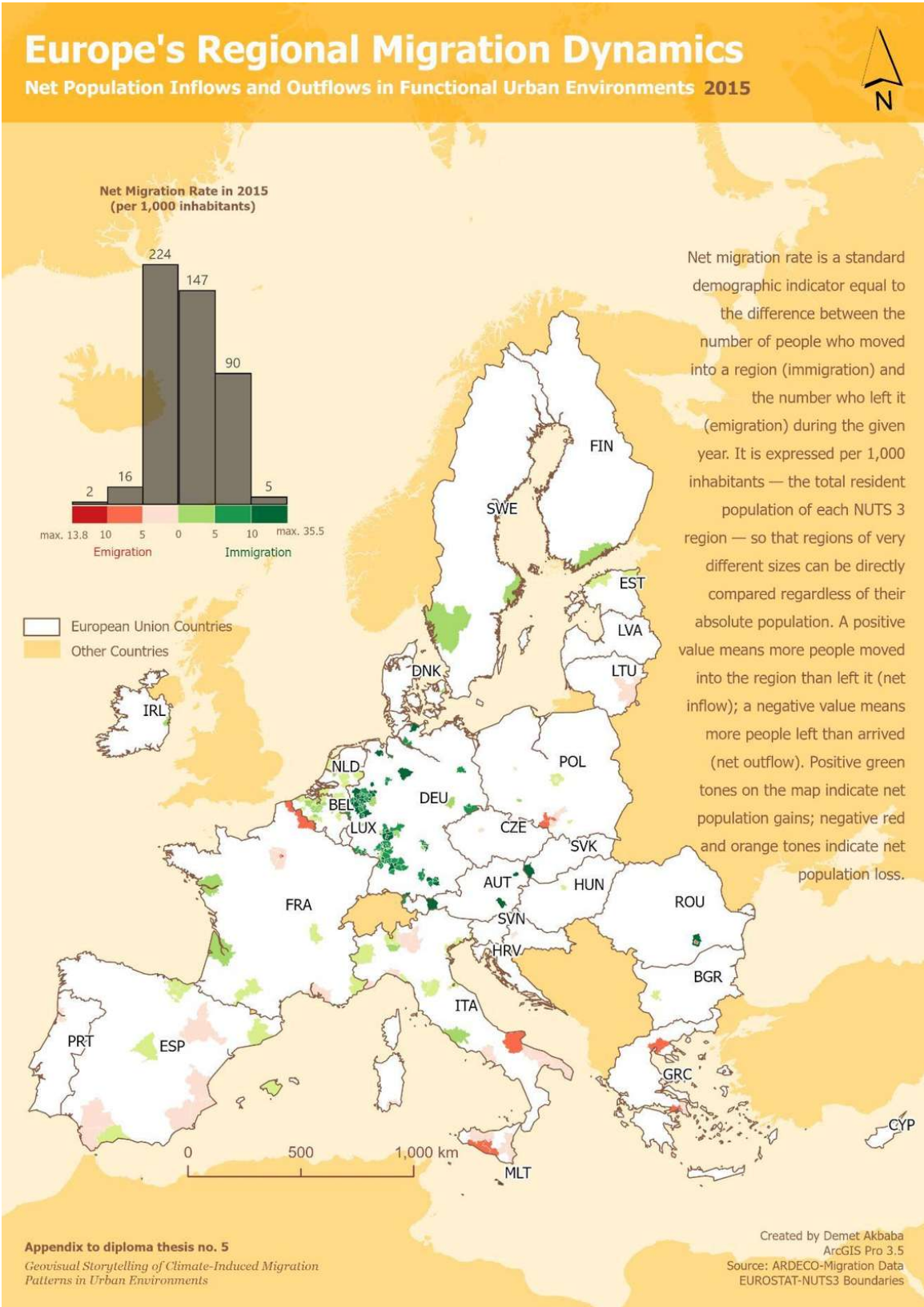


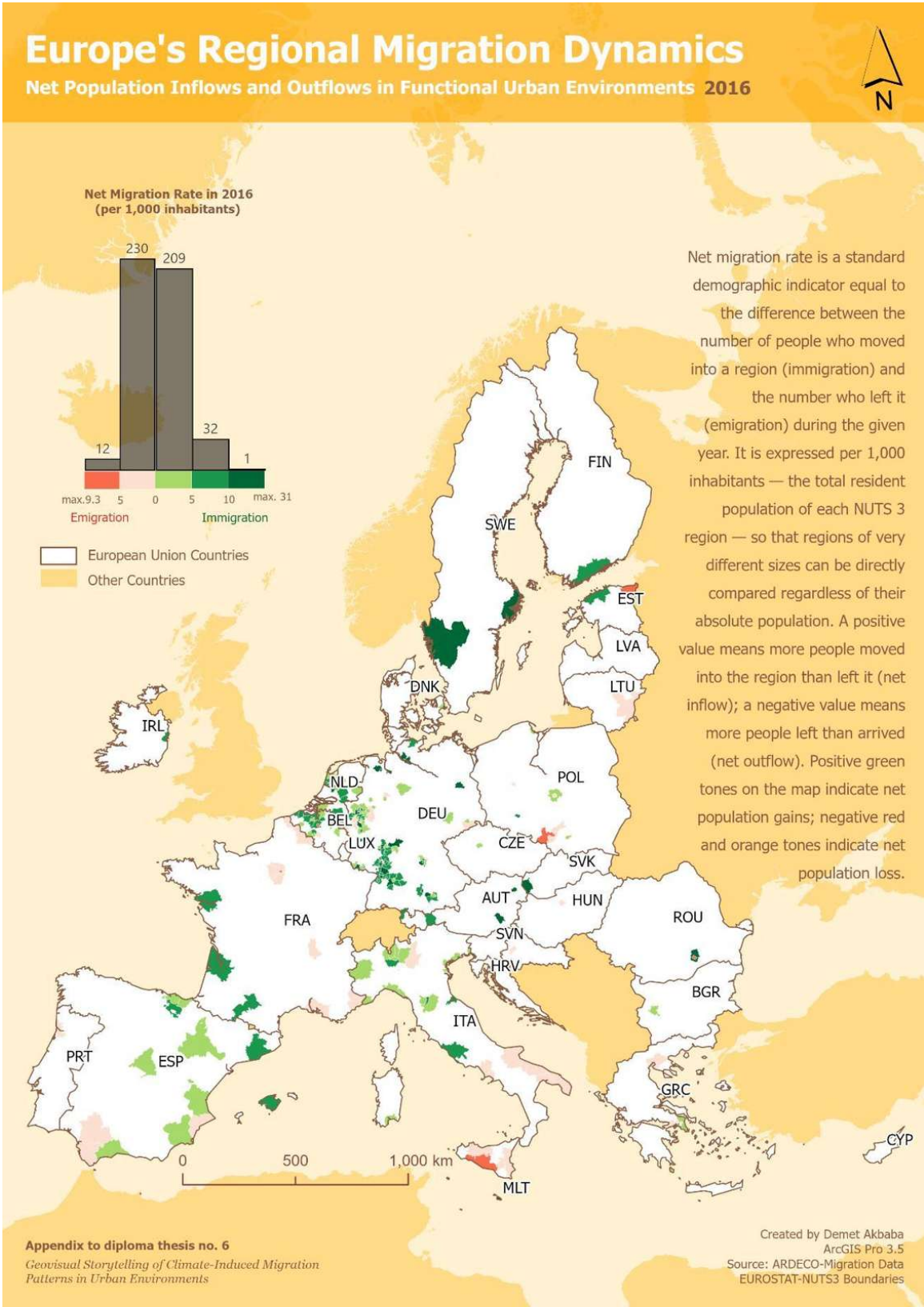


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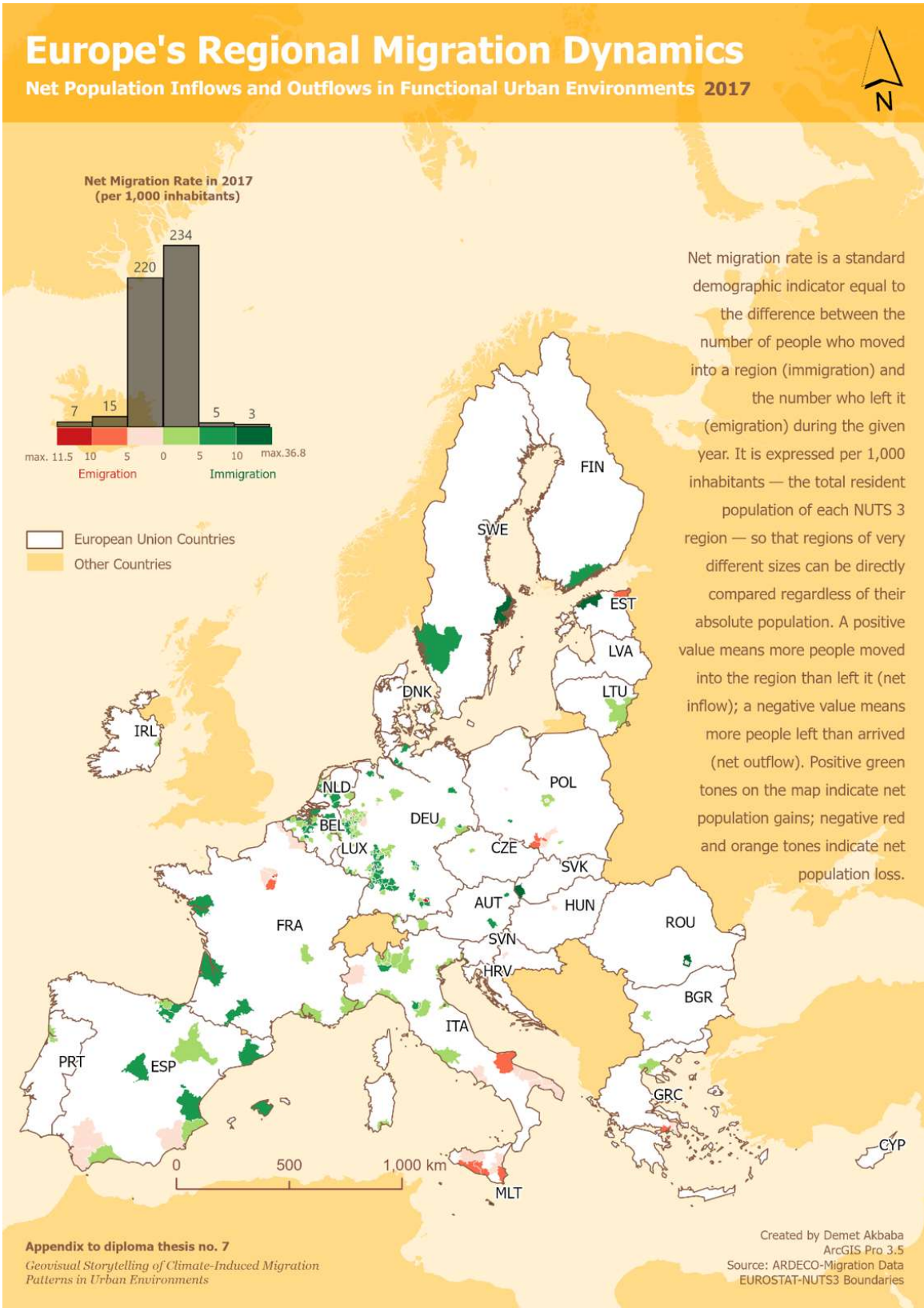
Attachment 4 - Economic Magnet

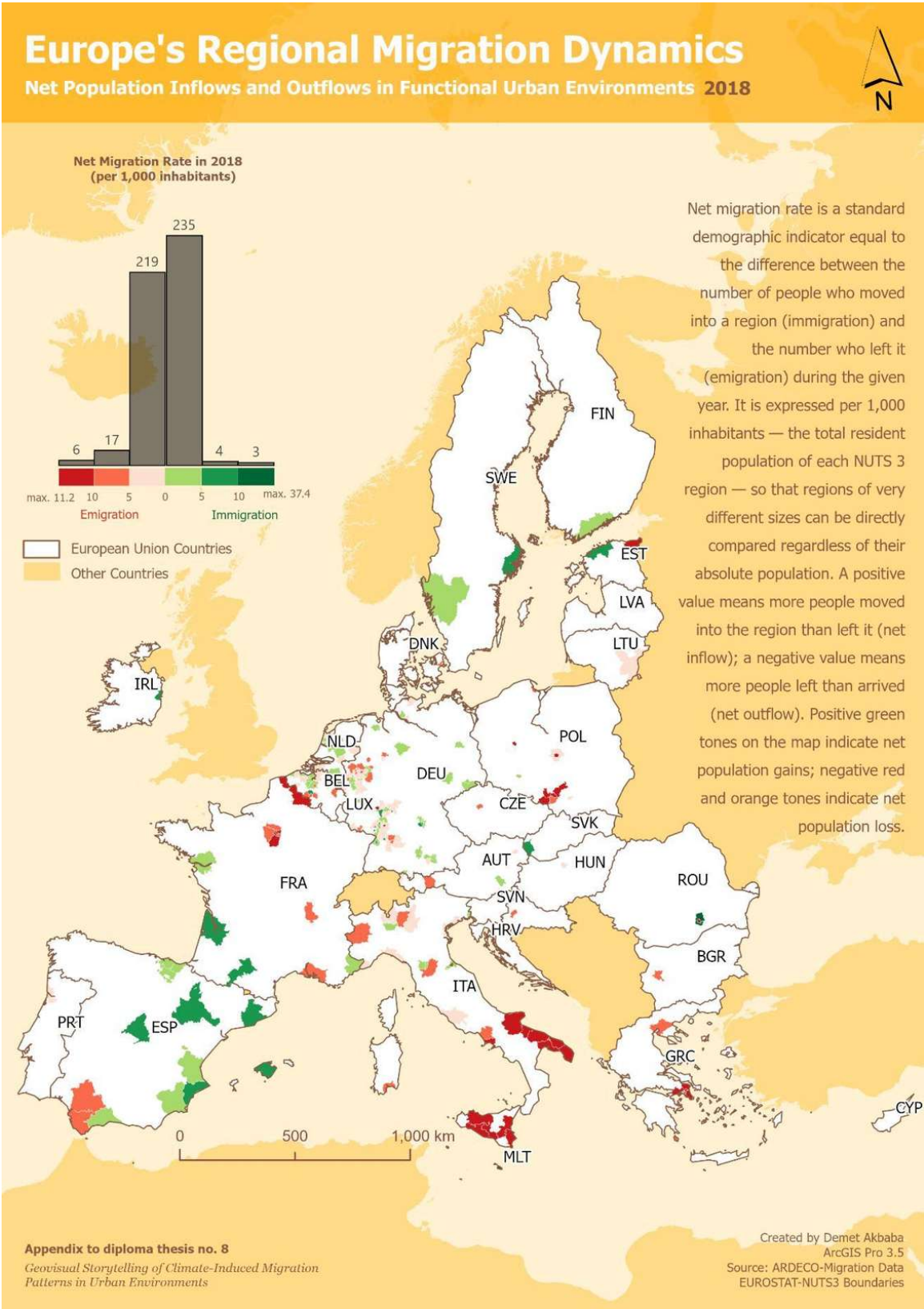


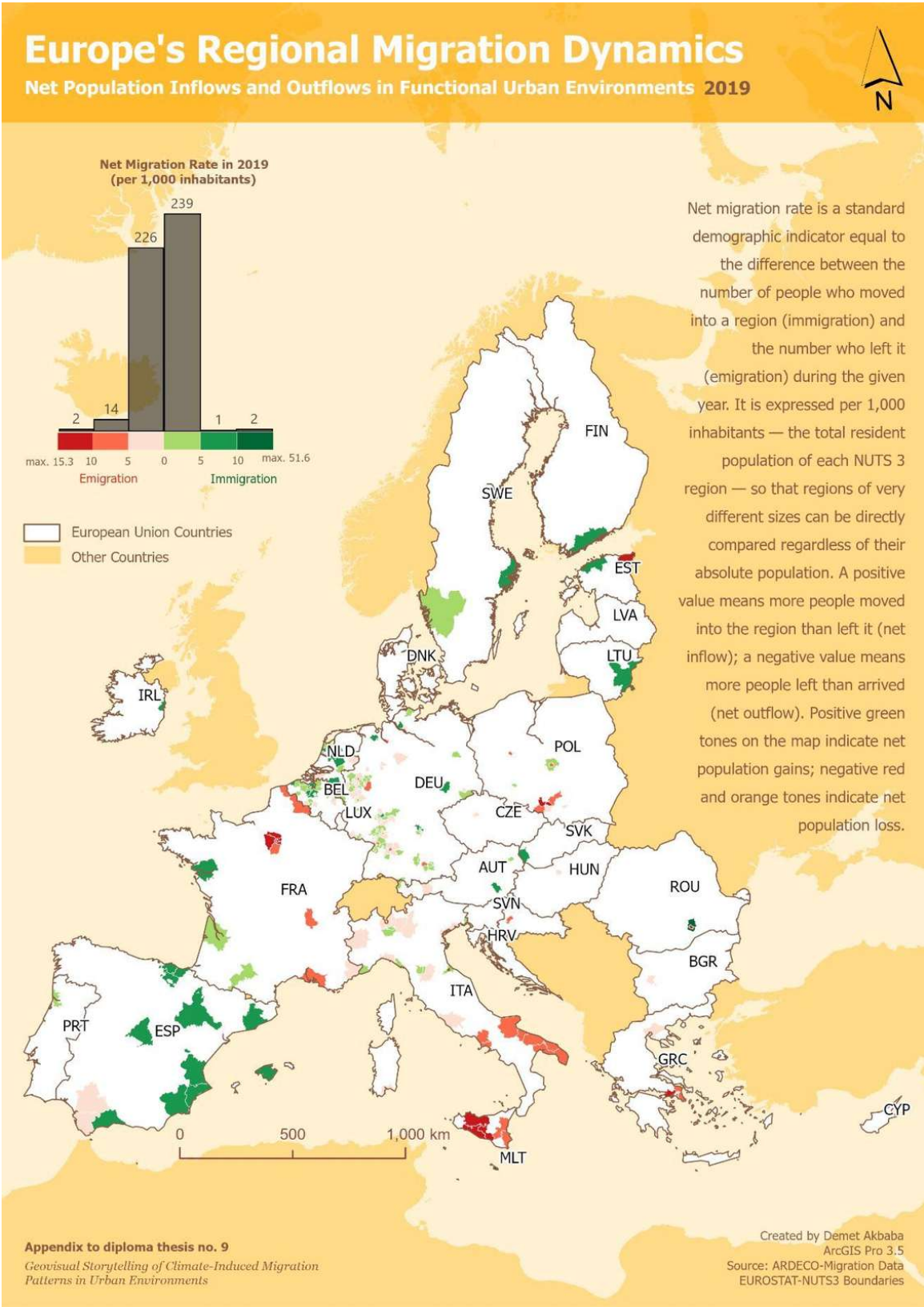


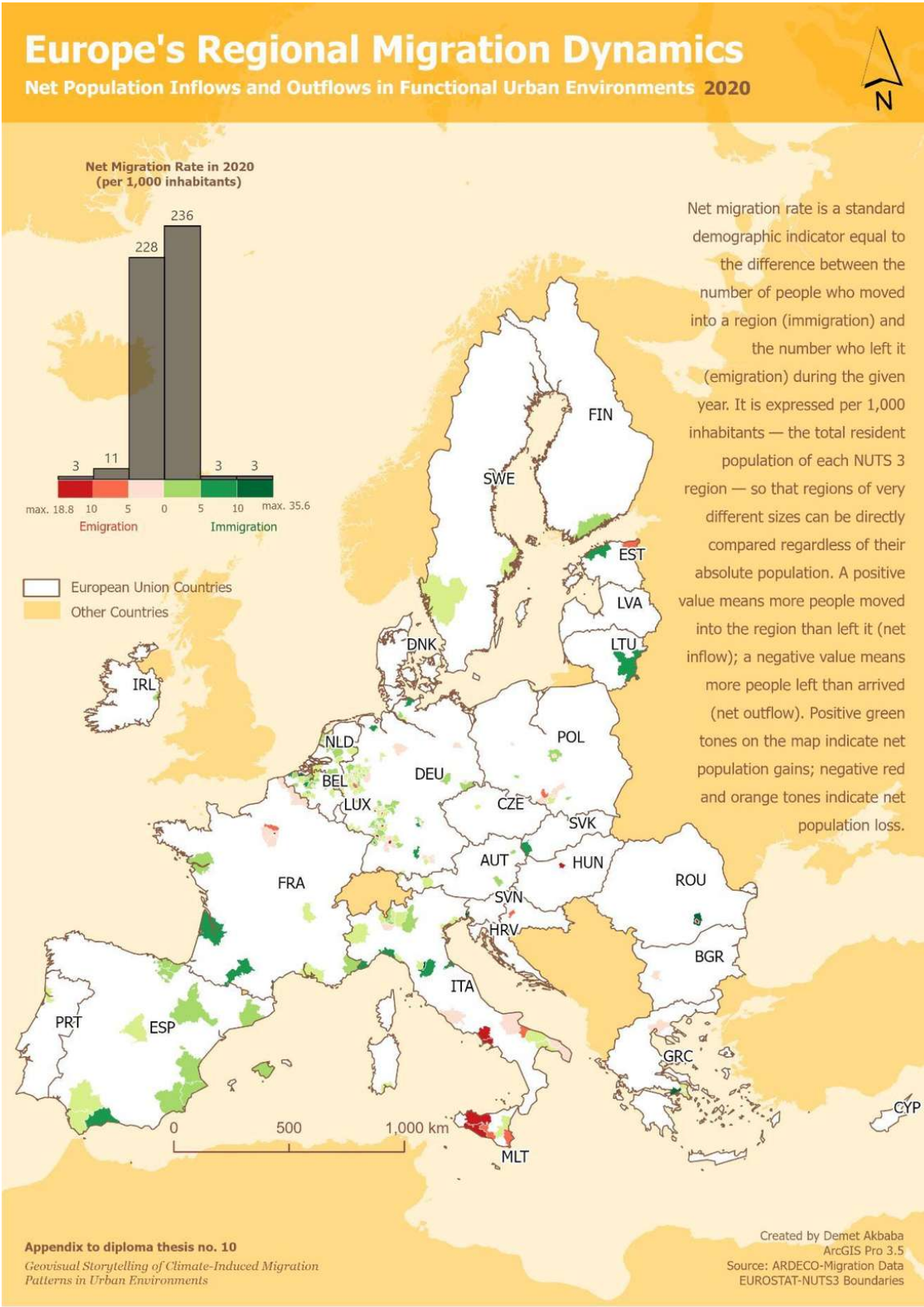


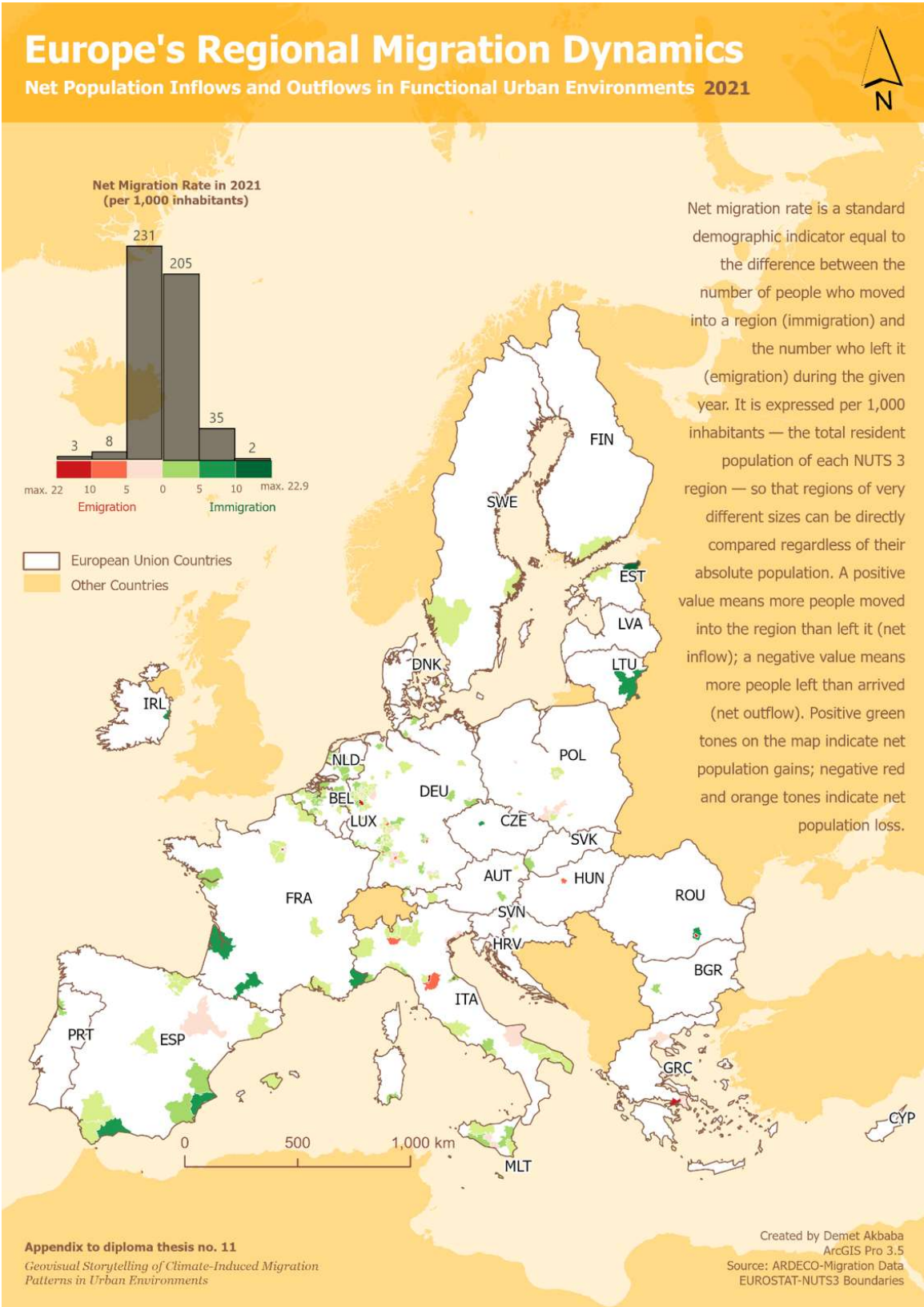
Attachment 7 - Demographic Heartbeat 2017

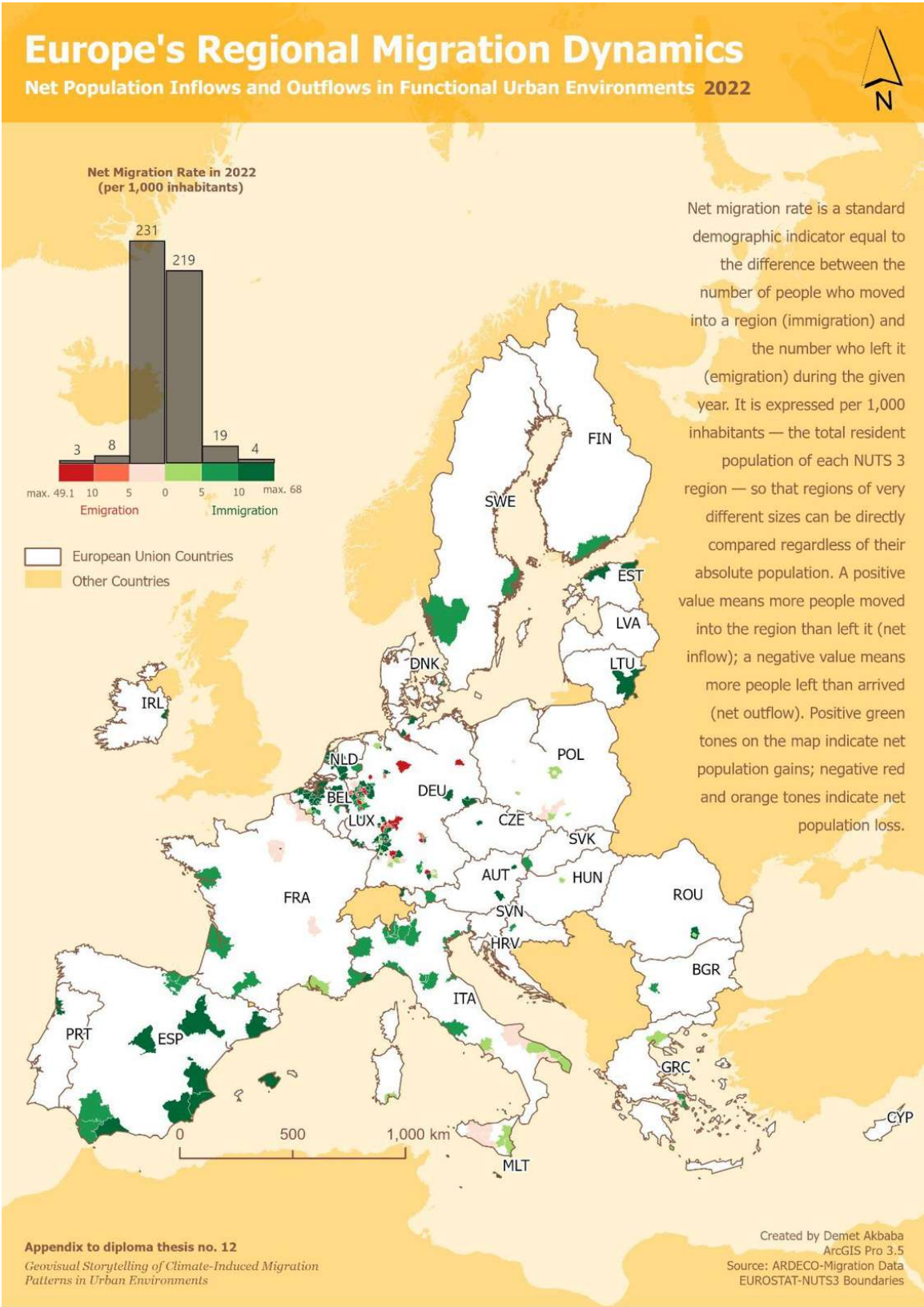


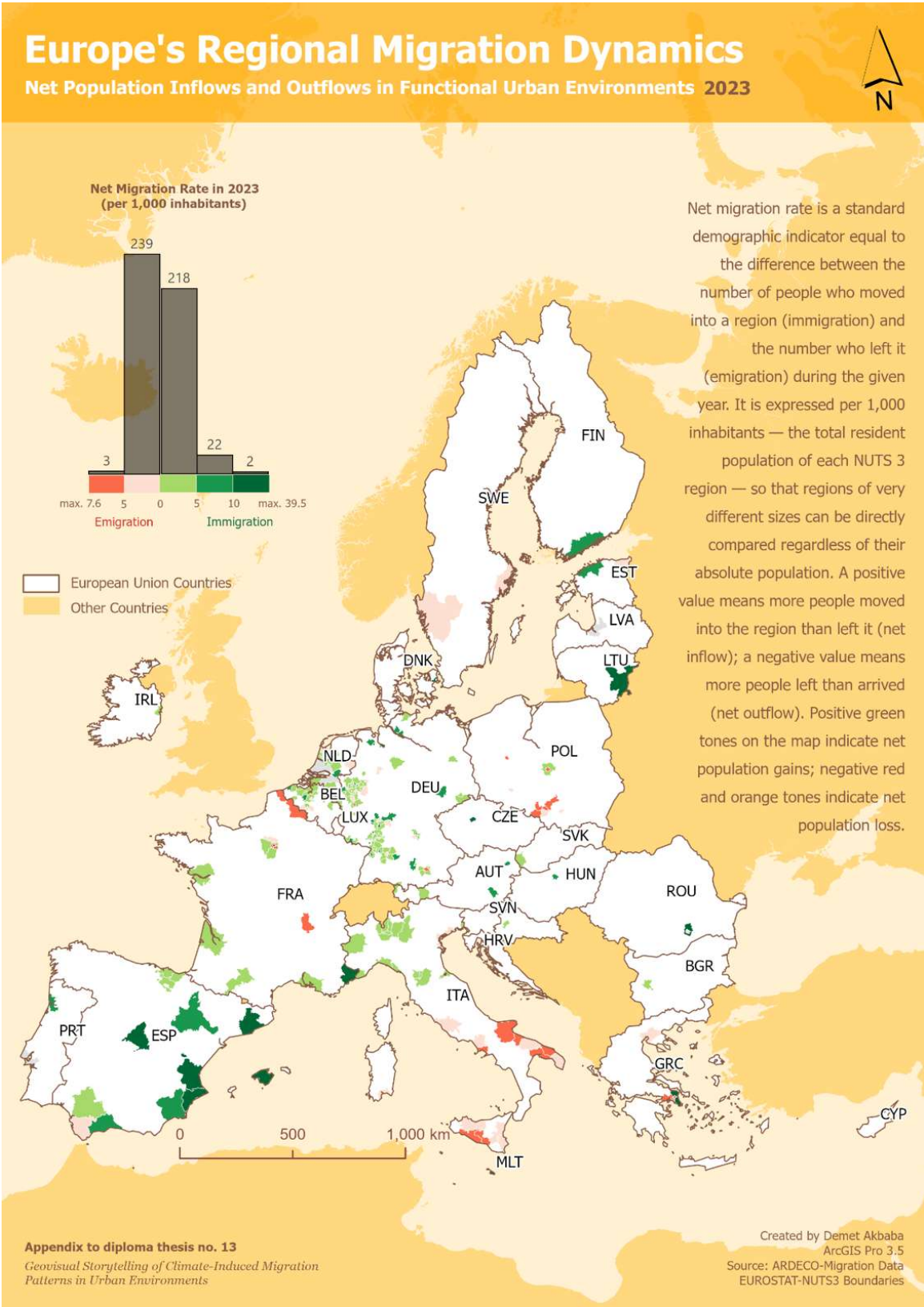


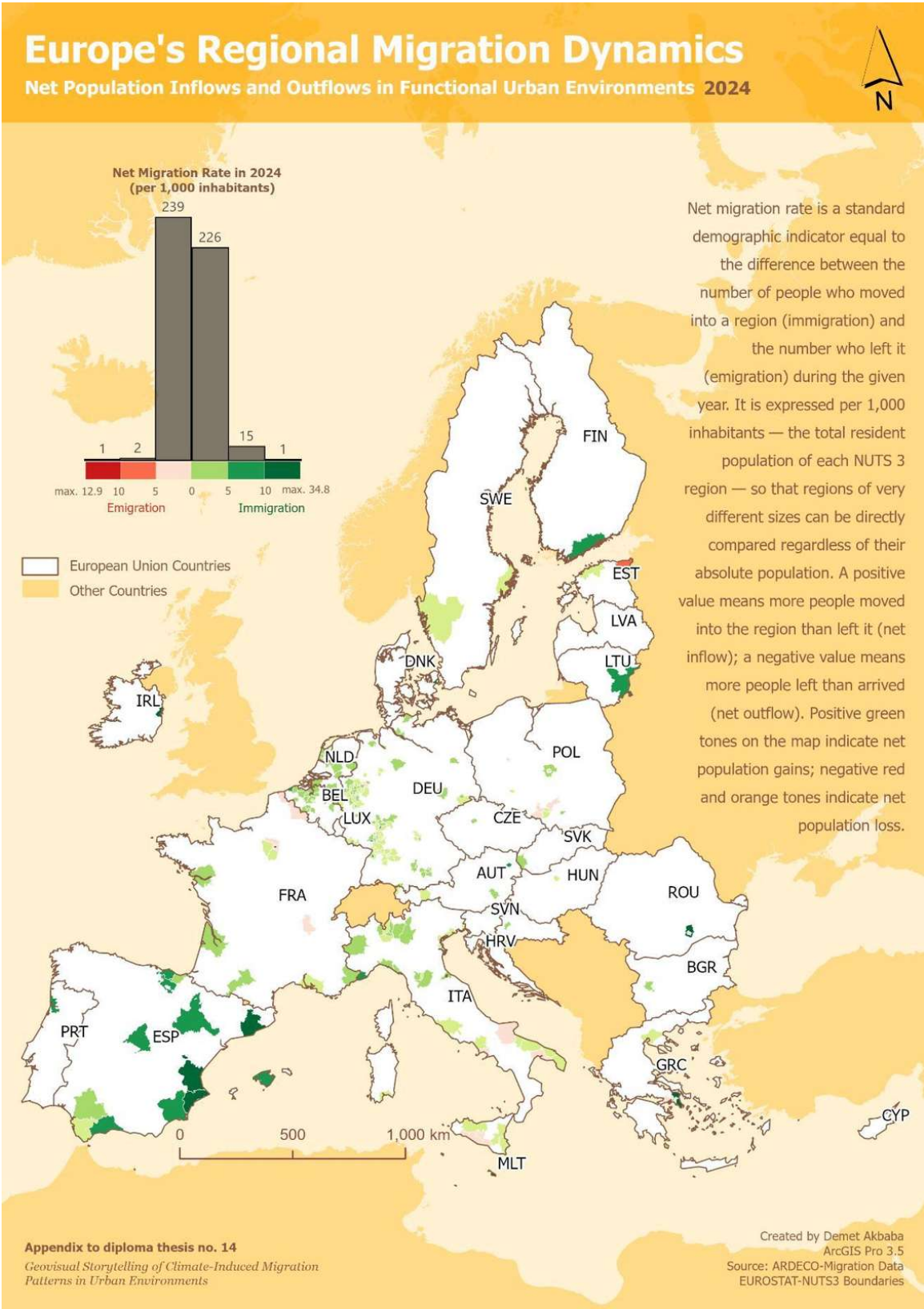




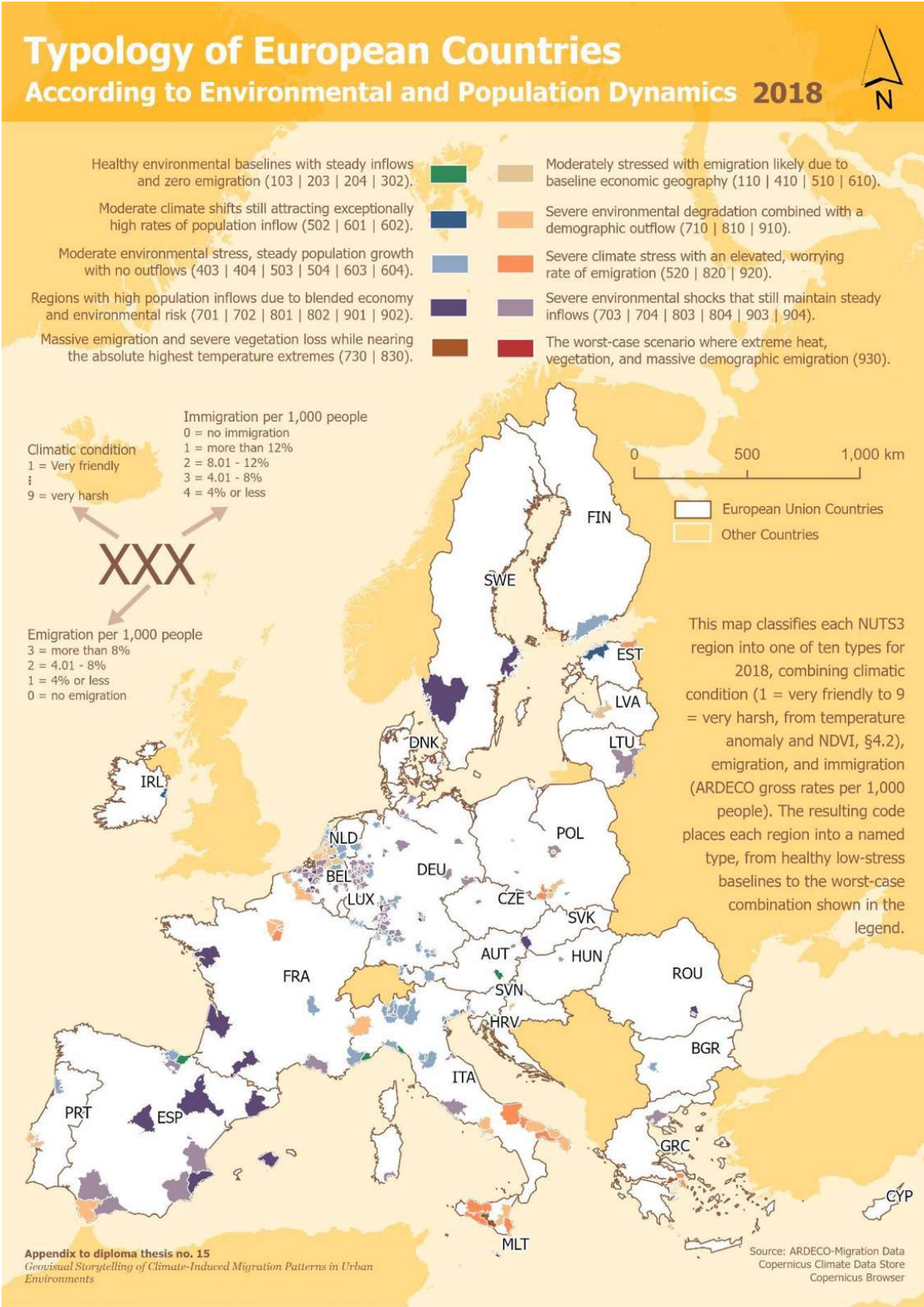


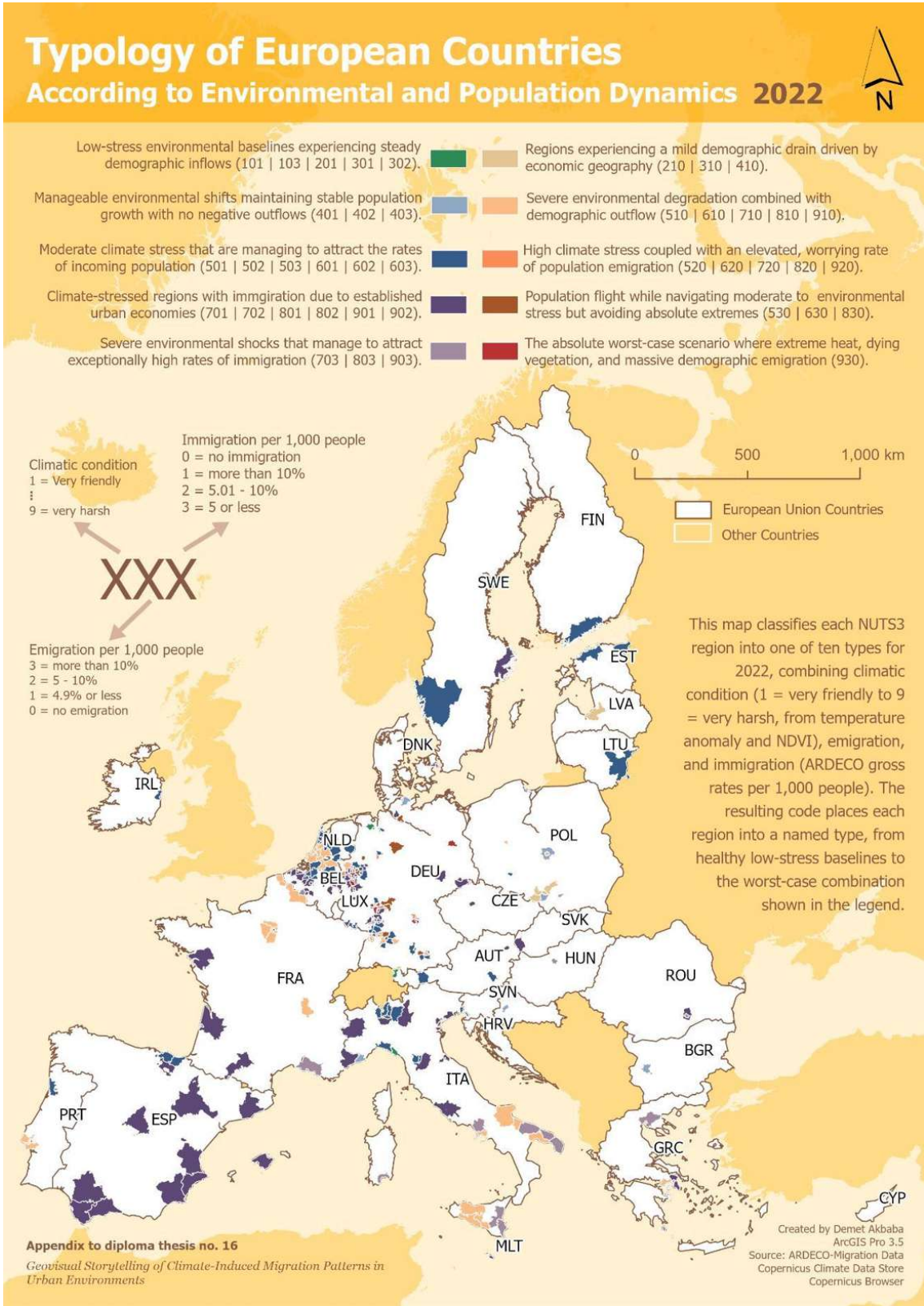




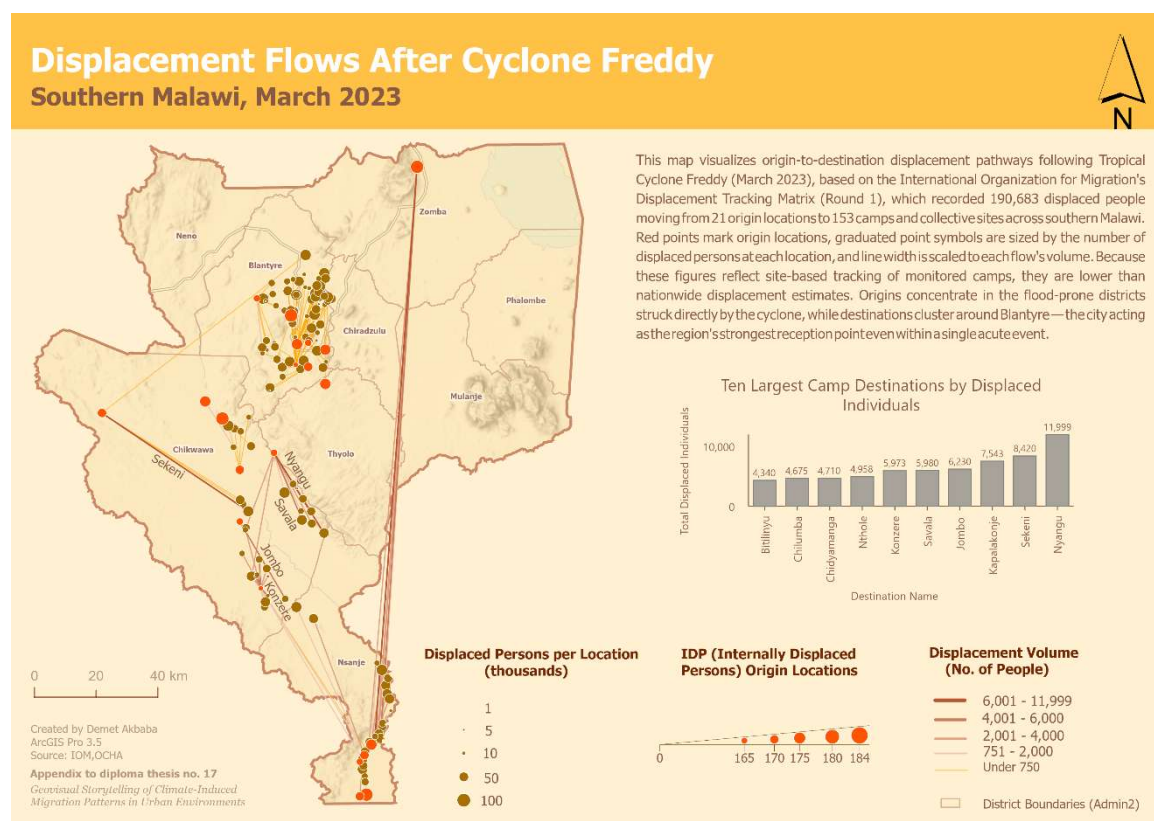


Attachment 15 - Typology of European Countries 2018

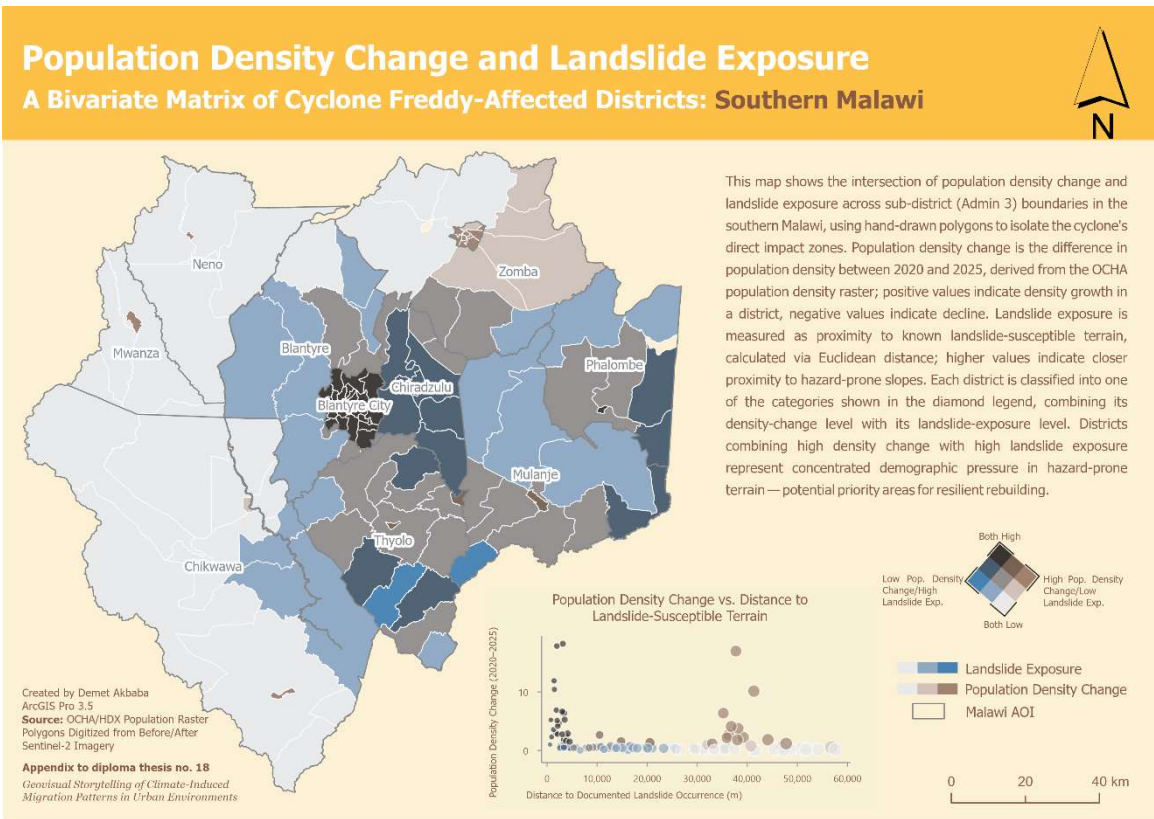




Attachment 17 - Displacement Flow (Malawi)



Attachment 18 - Bivariate Susceptibility (Malawi)



Attachment 19 - User Testing Questionnaire and Responses

The survey below implements the user testing methodology described in §3.9. It was distributed through Google Forms together with the published website link; participants were asked to explore the website independently before answering. For the task-based comprehension questions (Part B), the intended answer used for scoring is marked with ✓, participants did not see these marks.

User Testing: Climate Migration Storytelling Platform

B *I* U ↻ ✕

Thank you for helping to evaluate this master's thesis project, a website presenting a **Geovisual Storytelling Platform about Climate-related Migration and Displacement in Europe and Malawi**. Before answering, please explore the [website](#), including the "**The Story**" page that walks through the maps in sequence. There are no right or wrong answers about you; some questions check what the maps communicated to you, which tests the maps, not you. The survey takes about 5 minutes. Your responses will be reported anonymously in the thesis.

After section 1 Continue to next section ▼

Section 2 of 5

Part A: Background (1 question)

Description (optional)

A1. Which best describes your professional/academic background? *

- ☐ Urban planning / spatial planning
- ☐ Geoinformatics / GIS
- ☐ Other academic field
- ☐ Other

Part B: Task-Based Comprehension (4 questions)



Description (optional)

B1. (Climate Stress Grid) Comparing the Summer 2018 and Summer 2022 climate stress maps, where did the most severe stress concentrate in **2022**? *

- ☐ Germany and Scandinavia
- ☐ The Iberian Peninsula and France
- ☐ The Baltic states
- ☐ It stayed in the same place both years

B2. (Demographic Heartbeat) Looking across the ten yearly migration maps, in which period is an **increase in outgoing migration** most clearly visible after the 2018 drought? *

- ☐ Immediately, in 2018 itself
- ☐ In 2019–2021
- ☐ In 2022–2024
- ☐ No increase is visible in any year

B3. (Displacement Flow) After Cyclone Freddy, around which city do the displacement **destinations** cluster most tightly? *

- ☐ Lilongwe
- ☐ Blantyre
- ☐ Zomba
- ☐ The destinations are spread evenly across the region

B4. (Non-causal framing check) In your understanding, does the platform claim that climate stress **causes** the migration shown on the maps? *

- ☐ Yes, it shows climate stress causes migration
- ☐ No, it shows the patterns side by side and lets the reader compare
- ☐ Not sure

After section 3 Continue to next section ▼

Section 4 of 5

Part C: Design Ratings (1 question)



How much do you agree? (Likert, 1 = strongly disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = strongly agree)

The colours and legends made the maps easy to understand. *

- | | | | | |
|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| 1 | 2 | 3 | 4 | 5 |
| ☐ | ☐ | ☐ | ☐ | ☐ |

The Europe maps and the Malawi maps felt like parts of one coherent platform, even though they look different. *

- | | | | | |
|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| 1 | 2 | 3 | 4 | 5 |
| ☐ | ☐ | ☐ | ☐ | ☐ |

I would trust this platform as an input for a real planning or policy discussion. *

- | | | | | |
|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| 1 | 2 | 3 | 4 | 5 |
| ☐ | ☐ | ☐ | ☐ | ☐ |

Section 5 of 5

Part D: Open Feedback (1 question)

Description (optional)

D1. What, if anything, was confusing, or what would you improve? *

Long answer text

6 responses

[Link to Sheets](#)

Summary

Question

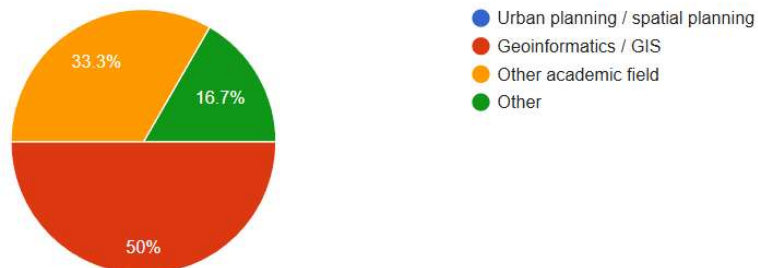
Individual

Part A: Background (1 question)

A1. Which best describes your professional/academic background?

[Copy chart](#)

6 responses

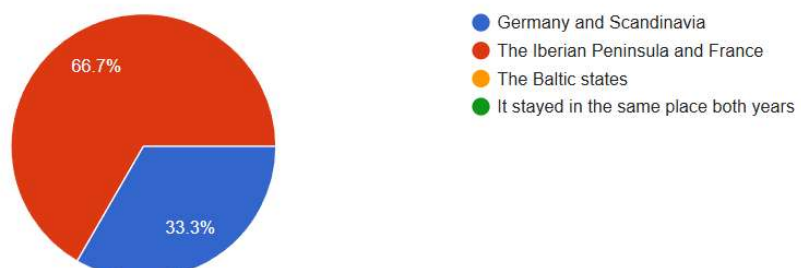


Part B: Task-Based Comprehension (4 questions)

B1. (Climate Stress Grid) Comparing the Summer 2018 and Summer 2022 climate stress maps, where did the most severe stress concentrate in 2022?

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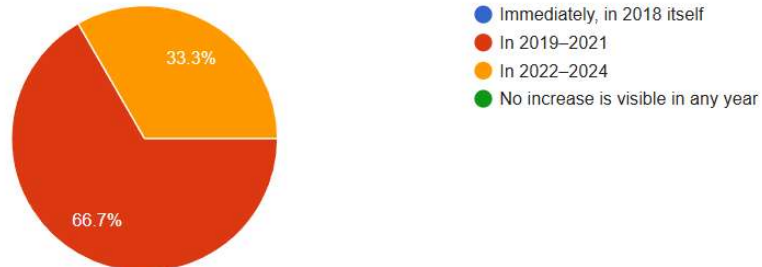
6 responses



B2. (Demographic Heartbeat) Looking across the ten yearly migration maps, in which period is an **increase in outgoing migration** most clearly visible after the 2018 drought?

[Copy chart](#)

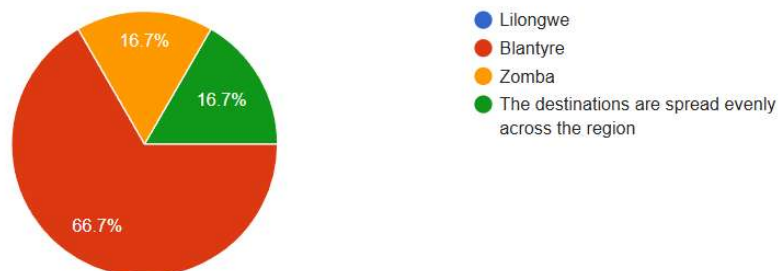
6 responses



B3. (Displacement Flow) After Cyclone Freddy, around which city do the displacement **destinations** cluster most tightly?

[Copy chart](#)

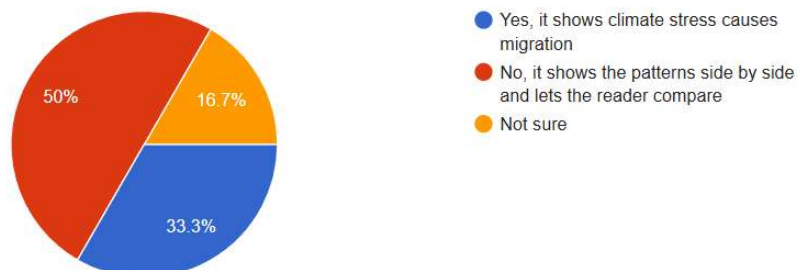
6 responses



B4. (Non-causal framing check) In your understanding, does the platform claim that climate stress **causes** the migration shown on the maps?

[Copy chart](#)

6 responses

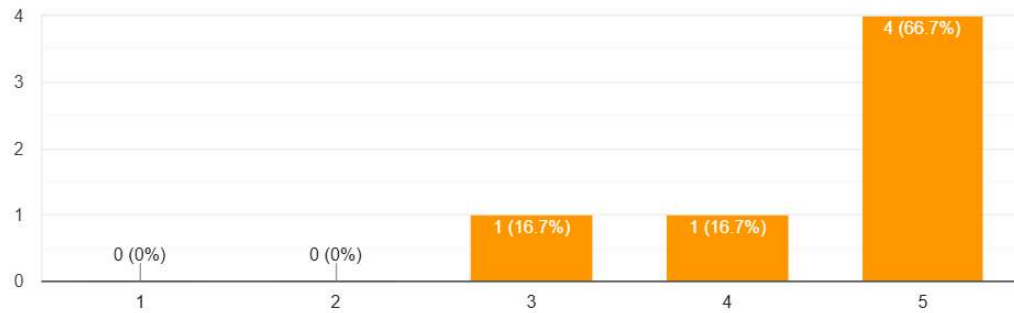


Part C: Design Ratings (1 question)

The colours and legends made the maps easy to understand.

[Copy chart](#)

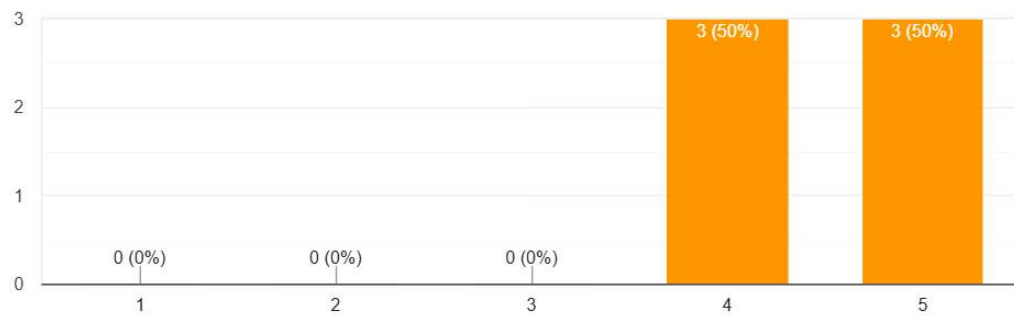
6 responses



The Europe maps and the Malawi maps felt like parts of one coherent platform, even though they look different.

[Copy chart](#)

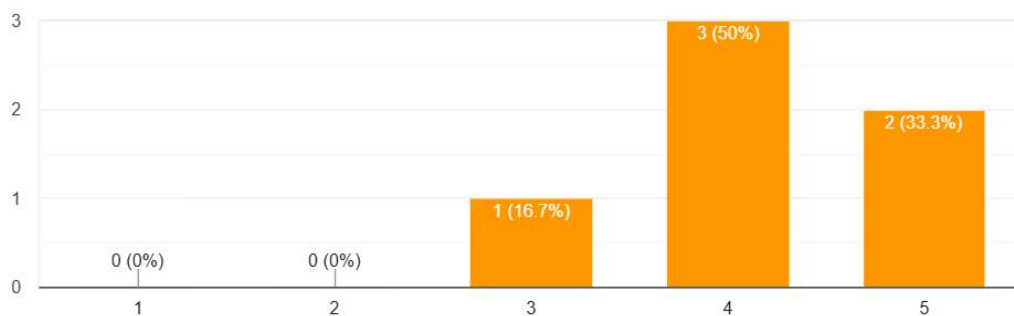
6 responses



I would trust this platform as an input for a real planning or policy discussion.

[Copy chart](#)

6 responses



Part D: Open Feedback (1 question)

D1. What, if anything, was confusing, or what would you improve?

6 responses

◆ Summarize responses

It was not easy to compare the maps. It would be better to overlay them on top of each other and use a swipe to compare.

For some one with a non GIS background (I'm a biologist) I felt overwhelmed by the information. If I'm told to sit and read for ~15 minutes or so, then maybe I would grasp more of it. But just skimming through it (which is what I understood you wanted Demet?), wasn't enough to make words and numbers stick in my mind. The colours inside the countries were nice, but there was too much yellow in the text and the backgrounds and everything else, I didn't even realise there were plots apart from the map themselves! But the fact that you could scroll and see the changes across the years was my favourite feature by far.

Also, I watched the whole website on my cellphone, so that also probably had an effect.

When bringing the example "Rhine-Ruhr is the densest spot on the whole map: 49 million people packed into a small area." maybe highlight the respective circles/points by grouping them with a form or different colour.

Nothing

Some maps could have been slightly larger. They should also be readable without having to click on them one by one. Especially Malawi maps. The sliding feature between years is good, but the maps are also not fitting the page properly. It's difficult to compare the map before and after. It would be better to have a clicking and sliding feature together with those maps. Otherwise, the maps are enough to convey the story they want to tell; the design and color schemes are good.

It would be great if you could record a video of yourself giving a presentation explaining the maps and graphs on the site and upload it to YouTube.