

Department of Built Environment

The interplay of environmental and social drivers of migration



A global synthesis

Venla Niva

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Over the recent years, human migration has risen to the top of the global agenda. Conflicts in the Middle East, Central America, Southeast Asia, and more recently in Europe have forced millions of people to flee. At the same time, hundreds of millions of people are moving from rural to urban areas as urbanization accelerates, especially in Africa and Southeast Asia. While conflict is perhaps the most tragic driver of human mobility, migration is also driven by multiple socio-economic and environmental factors. In fact, it is the interplay of socio-economic and environmental factors that is behind not only the decision to move but also behind outcomes of migration at the destination.

While there is conceptual clarity of the different drivers and outcomes of migration and their interplay, their geospatial and global representations are few. Thus, in this dissertation I address this gap by investigating 1) how human migration has developed in recent decades in different geospatial units; 2) what the key drivers of human migration are, and how these drivers have interplayed over time; and 3) what the implications of human migration are at both sending and receiving areas. In the analysis, I combine a qualitative conceptualization with quantitative analysis, the latter being carried out at a global level by utilizing spatially explicit, novel data that describe human migration and its social-environmental drivers from the past three decades. Quantitative analyses make use of spatial, exploratory and statistical methods, which allows a more comprehensive study of migration in different administrative units, rural and urban areas, and socio-environmental zonings.

The global analysis in my dissertation shows that the patterns of migration vary remarkably depending on the geospatial unit and scale used for the analysis; over the past two decades, migration between communes and provinces has been rising, while international migration has remained steady. Urban areas dominate as migration destinations at the global level, while the pattern becomes patchier at regional, national and sub-national levels, where rural areas have also experienced notable in-migration. Over the past three decades, the majority of migration has taken place in areas with medium-level human development and environmental stress, while socio-economic drivers – especially income and education – dominate environmental drivers globally. Finally, I demonstrate that factors of adaptive capacity are instrumental in shaping the outcomes of migration, especially in urban areas that have experienced accelerated population growth caused by in-migration.

In the coming decades, migration will continue to function as one of the methods of adaptation. Understanding these complexities and causalities behind human migration and its environmental and social dimensions is key in managing migration, especially in a future facing unprecedented and unforeseen changes.

Keywords human migration, environmental migration, integrative approaches, climate adaptation, adaptive capacity, urbanization, spatial analysis

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Tekijä

Venla Niva

Väitöskirjan nimi

Muuttoliikkeen ympäristöllisten ja yhteiskunnallisten ajureiden vuorovaikutus: Globaali synteesi

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Viimeaikaiset konfliktit Lähi-Idässä, Keski-Amerikassa, Kaakkois-Aasiassa, Afrikassa ja Euroopassa ovat pakottaneet miljoonia ihmisiä pakenemaan kodeistaan. Samanaikaisesti sadat miljoonat ihmiset muuttavat maaseudulta kaupunkiin muista syistä kaupungistumisen kiihtyessä. Vaikka konfliktit ovat kenties traagisin ihmisten liikkuvuutta aiheuttava tekijä, lukuisat muut yhteiskunnalliset ja ympäristölliset tekijät sekä niiden vuorovaikutukset vaikuttavat samanaikaisesti paitsi muuttopäätöksiin, myös muuttoliikkeen vaikutuksiin vastaanottavilla alueilla.

Muuttoliikkeisiin kytkeytyvistä tekijöistä vallitsee vahva käsitteellinen ymmärrys. Alueellinen ja eritoten globaali kvantitatiivinen tarkastelu on kuitenkin vielä vähäistä. Tässä väitöskirjassa tutkin 1) miten ihmisten muuttoliike on kehittynyt viime vuosikymmeninä eri maantieteellisillä alueilla; 2) mitkä ovat ihmisten muuttoliikettä selittävät tärkeimmät tekijät ja miten niiden vuorovaikutus on kehittynyt ajan myötä; ja 3) millaisia vaikutuksia muuttoliikkeillä on niitä lähettävillä ja vastaanottavilla alueilla. Tutkimus tarkastelee ihmisten muuttoliikettä ja siihen vaikuttavia sosiaalisia ja ympäristöllisiä tekijöitä kolmen viimeisen vuosikymmenen ajan (1990-2019) globaalilla tasolla spatiaalisia, kuvailevia, tilastollisia ja kvalitatiivisia menetelmiä sekä alueellisesti yksityiskohtaisia hila-aineistoja kehittämällä ja yhdistelemällä.

Väitöskirjani osoittaa, että muuttoliikkeen määrä ja vaikutus vaihtelee suuresti riippuen analyysissä käytetystä maantieteellisestä yksiköstä ja mittakaavasta. Kahden viimeisen vuosikymmenen aikana muuttoliike kuntien ja maakuntien välillä on kasvanut, kun taas kansainvälisen muuttoliikkeen määrä on pysynyt tasaisena. Globaalilla tasolla kaupungit ovat pääsääntöisesti olleet muuttovoittoisia, mutta on mielenkiintoista, että alueellisella ja kansallisella tasolla tarkasteltaessa useat alueet maaseudulla ovat vastaanottaneet enemmän ihmisiä kuin niiltä on lähtenyt. Viimeisten kolmen vuosikymmenen aikana suurin osa muuttovoitosta ja -tappiosta on keskittynyt alueille, joilla inhimillinen kehitys ja ympäristöstä aiheutuva rasitus on ollut keskitasoa tai sitä huonompaa. Sosioekonomiset tekijät, kuten tulotaso ja koulutus, selittivät sekä muuttovoittoa että -tappiota paremmin kuin ympäristötekijät, kuten kuivuus ja vesiriskit. Lisäksi yksilön ja yhteiskunnan kapasiteetti vastata tarkkarajaisiin haasteisiin on avainasemassa muuttoliikkeeseen kytkeytyvien lieveilmiöiden hallinnassa, erityisesti muuttovoittoisilla alueilla.

Muuttoliikkeen merkitys ihmisen sopeutumiskeinona tulee vahvistumaan tulevana vuosikymmeninä, ihmiskunnan kohdatessa ennenäkemättömiä ja ennalta-arvaamattomia muutoksia. Muuttoliikkeiden taustalla vaikuttavien ympäristöön ja yhteiskuntaan kytkeytyvien tekijöiden, niiden vuorovaikutuksen sekä monimutkaisten syyseuraussuhteiden ymmärtäminen on ensisijaista muuttoliikkeiden hallinnassa.

Avainsanat ihmisten muuttoliikkeet, integratiiviset lähestymistavat, sopeutuminen, sopeutumiskyky, kaupungistuminen

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Venla Niva

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List of publications

This doctoral dissertation consists of a summary and of the following publications which are referred to in the text by their numerals

- I. Niva, V.**, Kallio, M., Muttarak, R., Taka, M., Varis, O., Kummu, M. 2021. Global migration is driven by the complex interplay between environmental and social factors. *Environmental Research Letters*. DOI: 10.1088/1748-9326/ac2e86.
- II. Niva, V.**, Horton, A., Heino, M., Kosonen, M., Kallio, M., Kinnunen, P., Muttarak, R., Taka, M., Varis, O., Kummu, M. World's human migration patterns in 2000–2019 unveiled by high-resolution data. Manuscript accepted for peer-review in *Nature Human Behaviour* on the 26th of July 2022. Available as a pre-print in Research Square. DOI: 10.21203/rs.3.rs-1827424/v1
- III. Niva, V.**, Taka, M., Varis, O. 2019. Rural-Urban Migration and the Growth of Informal Settlements: A Socio-Ecological System Conceptualization with Insights Through a “Water Lens”. DOI: 10.3390/su11123487.

Author's contribution

I. Global migration is driven by the complex interplay between environmental and social factors

VN designed the research with support from MKu, OV and RM. VN was responsible for data collection and preparation. VN conducted the analyses with support from MKa. VN led the writing of the manuscript with contributions from all co-authors.

II. World's human migration patterns in 2000–2019 unveiled by high-resolution data

VN and MKu designed the research. Data collection and processing was led by MKu with help from AH, VV, MH, MKo, MKa, PK and VN. VN and MKu conducted the formal analysis. VN and MKu wrote the article with contributions from all co-authors.

III. Rural-Urban Migration and the Growth of Informal Settlements: A Socio-Ecological System Conceptualization with Insights Through a “Water Lens”

VN designed the research with MT and OV. Formal analysis and data curation was conducted by VN. VN led the writing with contribution from all co-authors.

1 Introduction

In recent years, human migration has risen to the top of the global agenda. Recent historical developments, such as the Syrian crisis in 2014–2015 and Russia’s attack in Ukraine in 2022, have forced millions of people to flee (Butler, 2017; UNHCR, 2022). At the same time, hundreds of millions of people are moving from their rural homes to urban areas as the pace of urbanization continues to accelerate (Adger et al., 2020; Aerni, 2016; Awumbila, 2017). Currently, the number of international migrants amounts to over 200 million people annually, while over 700 million move within their country annually (IOM, 2017, 2019a).

While conflict is one of the most visible and shocking drivers of migration, migration is driven by several other factors too. Better economic prospects, education opportunities, safety, and basic services are perhaps the most typical attractors, while sometimes environmental factors – such as prolonged droughts, floods and natural hazards – also push people to move (Adger et al., 2015; Black et al., 2011a). In short, migration provides the means for adaptation (McLeman and Smit, 2006) and is caused by a complex interplay of social and environmental factors at both the origin as well as destination (Black et al., 2011b), where the effects of migration range from increased development through remittances (Benveniste et al., 2021) to increased pressure on urban receiving agglomerates (Hoffmann and Muttarak, 2021). Indeed, migration presents one potential response to shifts in earth system dynamics, and in the future up to 3 million people are expected to fall out of the climatic space that has so far provided humanity with suitable conditions for life (Xu et al., 2020). Yet, as argued by Boas et al. (2019), the mechanisms and scale of migration remain under debate, and policy-making around migration in particular is fragmented and overshadowed by a lack of empirical evidence regarding migration and its drivers. Despite the fact that many different aspects of human migration have been identified and studied comprehensively, current knowledge is limited on three main fronts.

Firstly, many studies explore the drivers of human migration either from a social or environmental perspective. Despite the conceptual clarity over the fact that social and environmental factors drive migration through their interplay (Black et al., 2011b; Borderon et al., 2019), integrative approaches to assess this interplay are missing, especially in quantitative analyses. Second, global spatio-temporal analysis of migration has thus far been limited due to data constraints. High-resolution data of human migration are either from previous decades (at ~10km

resolution in de Sherbinin et al. (2015)) with coarse resolution (gridded national values at ~25km resolution in Alessandrini et al. (2020)), or at country level (Abel and Cohen, 2019). The lack of high-resolution global data is hindering global analysis of migration, its drivers, and their interplay, especially in low-income countries (Hoffmann et al., 2020; Piguet, 2022). Thirdly, the focus of migration research so far has been on the areas of origin, leaving destinations – especially cities – with less attention. This holds for both quantitative and qualitative analyses, despite the fact that understanding the conditions and effects of migration at both ends is vital in managing migration and its outcomes at national and international scales (Hoffmann and Muttarak, 2021). In the future, when the majority of the global population will reside in cities, the role of urban areas will become even more critical in managing migration (Adger et al., 2020).

This dissertation provides a data and literature–based global synthesis of human migration and its socio-environmental drivers over the past 30 years. The study takes an integrative approach by combining qualitative conceptualization with quantitative analysis to gain an empirical understanding of the magnitude and effects of global migration and its drivers over the past three decades. A historical perspective provides a prominent platform for enhanced understanding of future pathways of migration and its drivers. The following three research questions examine the development, conditions, drivers and implications of human migration:

RQ1: How has global migration evolved over the past 30 years and how is the phenomenon characterized across different geospatial units?

RQ2: What are the key drivers of human migration, and how has the interplay between these drivers changed over time in the origins and destinations of migration?

RQ3: What are the implications of migration in rural and urban areas?

2 Research background and gaps

Human migration has been a way to adapt to changing living conditions since the beginning of time (Bae et al., 2017). Today, migration takes place in various forms. Involuntary migration in the form of fleeing is typically induced by conflict or other hazards, be they of societal or natural origin or their combination. For example, a refugee crosses ‘an international border’ to another country, while displaced people flee for similar reasons, but remain in the country of origin. When voluntary, migration can be also short-term in the form of temporary and circular migration (IOM, 2019b). See text box 1 for definitions of different types of migration. In this dissertation, migration is mainly observed through net-migration, which simply describes the difference between in-migration and out-migration (IOM, 2019b) (Paper I and II), and internal migration from rural to urban areas (Paper III). Positive net-migration means that more people moved into a place than moved out, while negative net-migration means the opposite. Thus, this dissertation does not distinguish between involuntary and voluntary migration.

Box 1. Key types of migration

Forced migration can be caused by conflict or disaster, with the distinction of conflict caused by humans and disasters by natural environment. Can be temporary or permanent.

Refugees flee to another country because of “well-founded fear of persecution due to reasons of race, religion, nationality, membership of a particular social group or political opinion”. The status of refugees entitles them to international protection by law (defined in the 1951 Convention).

Asylum-seekers are individuals who are “seeking international protection” but have not yet received the refugee status.

Displaced persons are those who have been forced to flee within a country (internally displaced person, IDP) or across a border.

Voluntary migration

Labour migration refers to international migrants who have moved to another country in search of employment.

Urban migration (rural-urban/urban-urban/urban-rural/rural-rural migration) denotes migration to cities and urban agglomerates. Rural-urban migration is one of the driving factors of urbanization. This can be internal or international.

Temporary migration refers to migration “for a specific motivation and purpose with the intention that afterwards there will be a return to the country of origin or onward movement.”

Mixed migration takes place due to various drivers, motivations (voluntary & forced) and legal status (migrant vs. refugee).

Internal migration is movement within a country

International migration is the movement between countries

Net-migration is the difference between in-migration and out-migration.

In-migration > out-migration = positive net-migration
In-migration < out-migration = negative net-migration

IOM glossary on migration (IOM, 2019b)

2.1 Human migration and its drivers

The root causes or drivers of migration can be coarsely categorized into a few groups. The most traditional theories of human migration arrange the driving forces of migration around ‘pushing’ and ‘pulling’ factors (i.e. equilibrium and gravity models), of which the former describe the conditions in the sending areas and the latter the factors attracting people in the destinations (de Haas, 2011). In other words, the disparity between worse conditions in the origins, especially regarding income, and presumably better conditions in the destinations of migration is seen as the primary driving force of migration (Harris and Todaro, 1970; Lee, 1966).

The relationship between migration and income level, however, is not linear. Rather, it follows an inverted U-shape, the so called ‘migration hump theory’, whereby migration increases to a certain level of income and socioeconomic capacity, after which it begins to slow down (Martin and Taylor, 1996). This suggests that individuals with higher capacity can compensate the need to migrate with other ways of adapting (McLeman, 2018). Nevertheless, in a case where migration happens, factors such as the level of education, specific skills and capabilities, as well as system and society level factors such as efficiency and goodness of governance (Foresight, 2011) may shape the decision to move. For instance, studies show that functioning information technology and social networks are instrumental in sharing information about potential destinations (Boas, 2017; Seto, 2011).

Over the past three decades, environmental conditions have been under scrutiny as underlying factors of migration. Prolonged droughts in sub-Saharan Africa (Adaawen et al., 2019) and the Middle East (De Châtel, 2014; Gleick, 2014; Kelley et al., 2015), and degraded land in South America (Neumann et al., 2015) have been associated with migration events from several countries. Disasters such as Hurricane Katrina pushed thousands of people to flee in the US (Fussell et al., 2014), while floods (McLeman and Hunter, 2010), and sea level rise (Hauer et al., 2020) has resulted in similar events around the world. Despite it being widely accepted that the environment plays a role in migration, it should be noted that the role of the environment is rarely straightforward, but rather mediated through socio-economic factors (Hoffmann et al., 2020), as elaborated in the next section.

So far, however, much of the analysis of migration and its drivers have been conducted at national or regional scale (see e.g. Cameron (2018) for New Zealand, Baez et al. (2017) for Latin America and the Caribbean, Neumann and Hermans (2017) for the Sahel, and Borderdon et al. (2019) for sub-Saharan Africa), while global spatial analyses of human migration that go beyond country scale are scarce. De Sherbinin et al. (2012) and Neumann et al. (2015) studied human migration in hazardous areas and drylands globally by using gridded data covering three decades between 1970–2000, while Davis et al. (2013) mapped global migration patterns between 1960–2000, thus missing recent decades. More recent studies have linked human migration to environmental vulnerability globally, but only at national resolution (Grecequet et al., 2017). Furthermore, most of the analyses focus on sending areas, while less is known about receiving areas (Ayeb-Karlsson et al., 2020; Boas et al., 2019). Current knowledge is missing a global overview of how patterns of human migration vary in different geospatial scales and the effect of different socio-environmental drivers on migration at both at the origins and destinations.

Therefore, this dissertation provides a geospatial analysis of migration at multiple geospatial scales. The use of spatially explicit datasets allows the quantification of the amount of migration at sending and receiving areas globally (Paper I & II), as well as in rural and urban areas in different administrative units (Paper II). Further, big data of several environmental and social indicators are used to study the importance of individual drivers of migration at sending and receiving areas (Paper I), providing a novel and globally comparable overview on the factors of migration at its both ends.

2.2 Interplay between environmental and social drivers

As mentioned above, rather than being driven by individual environmental or socio-economic factors, migration is a result of complex conditions formed by the interplay of environmental and societal factors. One way of conceptualizing this interplay is through the concept of ‘migration as adaptation’, established in the mid-2000s (Black et al., 2011b; Foresight, 2011; McLeman and Smit, 2006). This approach frames migration as a process depending on human capacity and

environmental vulnerability (Figure 1); the ability to migrate and adapt increases in relation to the level of social, economic, and political capital, factoring in human agency in the context environmentally induced migration (Foresight, 2011).

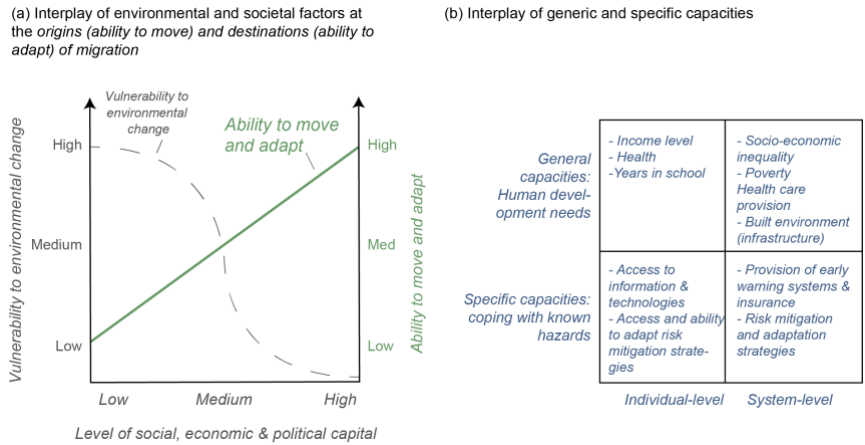


Figure 1. Interplay of environmental and social drivers behind human migration. Adapted from Black et al. (2011b), Eakin et al. (2014) and Papers I and III.

Indeed, coupling societal, social, as well as environmental factors in the diagnosis of human migration is crucial given it is ultimately a process framed by both human and natural dimensions. Framing migration as an adaptation method can be linked to the tradition of climate change and sustainability science literature, where adaptation and adaptive capacity are seen as a coping measure against system changes and stressors (McLeman and Hunter, 2010). More specifically, adaptation in human-nature systems reflects the response of individuals, groups (humans) and sectors, and regions of society to changing conditions (Smit and Wandel, 2006). However, quantitative analysis of the interplay of environmental and social drivers is in its infancy, most saliently at the global level.

Thus, the use of explicit data to build up a global gridded dataset allowed this dissertation to depict the interplay of various factors through an empirical analysis of several conceptual frameworks. In Papers I and II, socio-economic and environmental factors were used concurrently to create two different zonings describing the socio-environmental conditions of migration at its origins and destinations (Paper I), and also in rural and urban areas (Paper II). Understanding the interplay of factors is necessary not only for identifying where, when and why migration occurs at the sending areas, but also for understanding what shapes the outcomes of migration at the destination.

2.3 Different pathways of migration: implications and sustainability

While migration can function as an adaptation measure, there are several related social and environmental implications. Despite being an adaptive response to

conditions in the origin of migration, it is not unequivocal that migration always results in better prospects for life. In fact, people are as likely to move into equally vulnerable places as where they moved from (Adger et al., 2015; Black et al., 2011b). Migrants often confront discrimination and social exclusion (Ayebe-Karlsson et al., 2020; García-Cid et al., 2020), and large shares of migrants settle in underserved and impoverished areas with limited or no access to even the most basic services (Pantuliano et al., 2012; Reckien et al., 2017). Migration to urban areas presents a particular issue in these regards. (Internal) migration to urban agglomerates is one of the primary reasons for urbanization especially in many African countries, but also in South-East Asia where urbanization continues to accelerate and informal urban settlements continue to persist and grow (Adger et al., 2020). Many migrants use informal settlements as ‘waiting rooms’ upon their arrival to an urban area (Tacoli et al., 2015), while many are trapped in these areas with limited and restricted capacity to return or change location (Ayebe-Karlsson et al., 2020).

In other words, adaptations and their outcomes depend on multiple capacities that cross different levels of society. Eakin et al. (2014) divided adaptive capacity into specific and generic capacities at both individual- and system-level (Figure 1b) which shape adaptations: Individual-specific capacities could mean specialized farming practices and the knowledge and access to early warning systems related to weather forecasting, while general system-wide capacities reflect the “fundamental human development goals” of a society, such as health, education and safety. Together, these capacities form the adaptive capacity of individuals and further societies to proact and react to different perturbations, such as environmental changes; migration reflects a reactive or proactive process used by individuals to adapt or mitigate the changed conditions for life and livelihoods (McLeman and Smit, 2006). It thus presents a process dependent on both individual- and system-level capacities and the different stressors, opportunities and services of the environment. These in turn shape the decision to move, as well as the outcomes and sustainability of migration.

However, too little attention has been paid to the conditions of migration at the destinations (Boas et al., 2019), or to studying the characteristics of sending and receiving areas simultaneously, despite their impact on one another (Hoffmann and Mutarak, 2021). Indeed, in a recent paper, Piguet (2022) asks two relevant questions: “Does mobility and migration allow for better adaptation?” and “what are environmental migration destinations?”. Hence, in this dissertation I apply a critical approach to examine the feasibility of migration as an adaptation method by exploring the potential pathways of migration in a rural-urban system (Paper III). The concept of generic and specific capacities breaks down the overly general factors of adaptive and human capacity (as used in Papers I and II) into more detailed ones that better reflect the decision to move. This is ultimately a combination of individual capabilities of individuals, but is also strongly influenced by institutional and societal capacities that enable and maintain people’s opportunities to practice their livelihoods (for instance, through

governance). A quantitative approach is then used to study the impact of migration on population growth/decline and to estimate the pressure of migration on rural and urban locations in certain socio-climatic conditions, describing the generic capacity of the location (Paper II).

3 Methods and data

3.1 Methods

The dissertation employs a mix of quantitative and qualitative methods that are suitable for large spatio-temporal data sets and global-scale analysis. Table 1 summarizes the methods used. Quantitative analysis was used for studying large global datasets, while qualitative methods were used to synthesize literature. A mixed-methods approach is advantageous, as it provides better means for understanding a multifaceted phenomenon than either a quantitative or qualitative approach alone (Creswell and Plano Clark, 2017; Molina-Azorin, 2016). All quantitative analyses were performed in RStudio (RStudio Team, 2021).

Quantitative analysis in this dissertation is formed by three methodological approaches: spatial, exploratory, and statistical methods. Prior to any descriptive analysis for spatial data, a *zonal analysis tool* (Hijmans, 2021, 2019) was used to aggregate spatial gridded data into lower resolution or larger units of analysis, or over a temporal scale. For instance, in Papers I and II, zonal-sum was used to aggregate gridded net-migration to different administrative levels and socio-environmental bins. The zonal tool was also used to harmonize the resolutions of different datasets used for the analysis. *Exploratory data analysis (EDA)* was then used to identify overall patterns and characteristics from large datasets (Tukey, 1977). Here, *graphical techniques* of EDA were used to visualize aggregated data as heatmaps, bar-plots and maps. For instance, in Paper I, the visualization of spatial data as global maps provides a way to detect regional differences in feature importance measures, while *descriptive statistics* were used to identify key features of the data, such as annual means or cumulative sums on net-migration in certain zones, as done in Paper II.

Statistical methods were used to investigate the explanatory power of several different variables in relation to net-migration. In Paper I, *random forest regression* (Wright and Ziegler, 2017) was used to quantify the importance of explanatory variables in explaining positive and negative net-migration. ‘Random forest’ is a simple machine learning method based on decision trees. Ultimately, random forests are ensembles of decision trees, each of which produces a prediction of the response variable by using a random set of explanatory variables. The overall prediction of a forest is then formed through a ‘consensus regression

fit', or in simple words, the most common prediction among individual trees. Explanatory power of explanatory variables can be determined by deriving feature importance measures from each RF regression model. Feature importance is determined through the increase in prediction error (mean square error calculated from the test/out-of-bag sample). This means that the higher the importance, the higher the explanatory power. Here, the explanatory variables were selected based on previous literature that identified drivers of human migration (See Section 2.1). For environmental variables, for instance, I selected variables which represented both slow-onset (drought and water risk) and rapid environmental changes (natural hazards), while food production scarcity was selected as a proxy for food insecurity. Openly available data was preferred in this study, and it further directed the selection of variables (see Paper I for a more detailed rationale).

Qualitative analysis was used in Paper III to build a conceptualization following a hypothesis which links rural-urban migration to the growth of informal urban settlements (see e.g. Stoler et al. (2021) for similar approach). A concept was formed by utilizing a framework provided by Eakin et al (2014) (see Section 2.3) with the intention to critically examine the suitability of migration as an adaptation method. Using the framework, literature was reviewed to identify different factors of adaptive capacity over environmental, economic and social domains, and to identify what kind of migration outcomes their interactions could produce. Three global initiatives were then screened to see if such interactions are acknowledged in urban development policies. For screening the literature, narrative literature review approach was used. Such reviews intend to encourage discussion by synthesizing literature around a certain hypothesis, and provide an extensive overview of a certain topic (Green et al., 2006). It should be noted that the method does not intend to follow any protocol for search words or inclusion/exclusion criteria for articles.

Table 1. Methods and tools used in the dissertation publications.

| Methods | Tools | Paper I | Paper II | Paper III |
|-----------------------|---|---------|----------|-----------|
| Quantitative analysis | | | | |
| Spatial | Zonal analysis tool | x | x | |
| Exploratory | Visualization of data and visual inspection of maps and plots | x | x | |
| | Descriptive statistics | x | x | |
| Statistical | Random forest regression (Feature importance analysis) | | x | |
| Qualitative analysis | | | | |
| Literature review | Narrative literature review | | | x |

3.2 Data

The majority of the data utilized in the appended articles of this dissertation were acquired from open access databases. A majority of these data were provided as global grids for various time periods. Table 2 lists the most relevant datasets used in the quantitative analyses conducted in the dissertation. The data include several demographic, socio-economic, and environmental datasets, covering multiple decades.

Additionally, new datasets were produced in the appended papers. A global gridded dataset of annual net-migration for 2000–2019 was constructed for Paper II. For the construction, openly available tabulated census data of the world's countries were collected and then processed into global grids. Tabulated data were downscaled with linear regression by using four parameters (Human Development Index, population density, the share of women of reproductive age of total population, and the share of life lived for an average person), and then harmonized for each country to match the total birth and death rates reported by the United Nations and World Bank databases. By comparing these reported birth and death data to modelled global population counts (WorldPop, 2021), it was then possible to create gridded net-migration rasters. Both in the produced data, and in the data used in Paper I, net-migration is reported at 5 arc-min resolution (~10x10km grid cell). This means that a net-migration value (a number telling how many more people moved into the cell than moved out (positive net-migration) or vice versa (negative net-migration)) was computed for each cell. Thus, the data here capture migration only between pixels, not within them.

Additionally, in Paper II, urban extent rasters were created to map urban and rural areas globally for each year over 2000–2019, and to study net-migration in urban and rural areas separately. Urban areas were mapped by using scaled population density (between 0–1) grids for the respective years, and then classifying the grid cells of each country so that all cells with the highest population density would be classified as urban until the cumulative sum of population from these cells met the national limit for urban population. The net-migration data, urban extents, and all appended datasets will be made available in an open repository upon publication. All datasets produced in Paper I are available at: [10.5281/zenodo.5562038](https://zenodo.org/record/5562038).

The qualitative analysis conducted for this dissertation was based on peer-reviewed scientific literature and policy documents, as well as reports and working papers produced by organizations such as the United Nations. The literature was collected through well-established search engines and scientific databases, such as Scopus, Web of Science, and Google Scholar.

Table 2. Examples of the datasets used in the analyses of Papers I and II in this dissertation. Datasets marked with an asterisk (*) are produced by the author. List of the datasets used to construct these datasets are provided in the appended papers. For full dataset list, see Papers I and II.

| | Data and source | Paper I | Paper II |
|----------------|--|------------|-----------|
| Socio-economic | Income (Kummu et al., 2018; Smits and Permanyer, 2019). | 1990–2000 | |
| | Education (Kummu et al., 2018; Smits and Permanyer, 2019). | 1990–2000 | |
| | Health (Kummu et al., 2018; Smits and Permanyer, 2019). | 1990–2000 | |
| | Governance (Varis et al., 2019; WGI, 2018). | 1990–2000 | |
| | Human Development Index (Kummu et al., 2018). | | 2000–2020 |
| Environmental | Natural hazards (Varis et al. (2019); adapted from Dilley et al. (2005). | 1990–2000 | |
| | Drought risk (Vicente-Serrano et al., 2010). | 1990–2000 | |
| | Food production scarcity (Klein Goldewijk et al., 2010; Mueller et al., 2012) | 2000 | |
| | Water risk, Aqueduct global maps 3.0 (Hofste et al., 2019) | X | |
| | <i>Baseline water stress</i> | 1990–2000 | |
| | <i>Unimproved/No Drinking water & sanitation</i> | 2015 | |
| | Global aridity index (Trabucco and Zomer, 2018) | | 1970–2000 |
| Demographic | Net-migration (de Sherbinin et al., 2015) | 1990–2000 | |
| | Population counts, HYDE 3.1 (Klein Goldewijk et al., 2010) | 1990, 2000 | |
| | Population counts, WorldPop (WorldPop, 2021) | | 2000–2019 |
| | Global net-migration estimates for 2000-2019 * | | 2000–2019 |
| | Urban extent rasters * | | 2000–2019 |

4 Results

This section presents the key findings of this research. The development of human migration from 1990 until 2019 are presented in Section 4.1 (RQ1). The interplay of environmental and societal factors of migration (RQ2) are presented in Section 4.2, while the implications of environmental migration are presented in Section 4.3 (RQ3).

4.1 Global patterns of human migration between 2000–2019

By using high-resolution global data, this dissertation demonstrates that globally, the amount of international migration has stayed relatively steady, in contrast with inter-provincial migration, which has almost doubled since the beginning of 2000 (Figure 2, Paper II). Inter-communal¹ migration on the other hand has declined, especially after the Arab Spring in the early 2010s.

¹ Here, a commune refers to 2nd level administrative unit. For instance, in the US a commune would refer to a county, while a province would refer to a state. Because the terminology for different administrative units is not consistent across the world, commune and province are used when referred to 2nd and 1st level administrative units, country level being the coarsest one (level 0) in the GADM mapping.

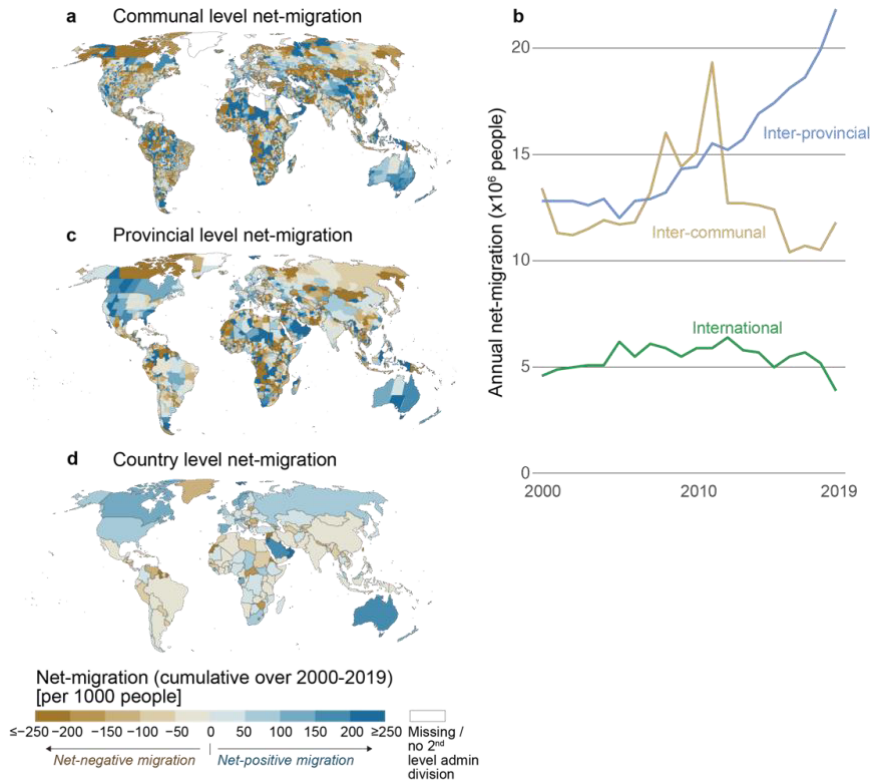


Figure 2. Accumulated net-migration (per 1000 people) over 2000–2019 for communal, provincial, and country levels (a, c, d). Cumulative net-migration (per 1000 ppl) between communes, between provinces, and between countries for each year between 2000–2019 (b). Modified from Paper II.

Paper II revealed considerable spatial variation in human migration across the globe. The largest accumulated in-migration per population ratios can be observed in the Arabian Peninsula, Australia, and Western Sahara, whereas the accumulated net-negative migration per population size at the country level was relatively low in most parts of the world. Central African Republic and Syria presented the highest net-negative migration ratio, reflecting the prolonged conflicts in these countries. However, when zooming in to provincial and communal level, the patterns become patchier (Figure 2). Paper II showed that especially large countries such as the US and China depict a clear pattern of net-negative migration in the inland provinces and communes and net-positive migration in coastal areas over the past two decades. Both countries accommodated their largest urban agglomerates in coastal regions, explaining the mobility from rural inland to coastal urban areas.

I also investigated net-migration in urban and rural areas separately (Paper II). At the global level, urban migration remained net-positive throughout the study period, while rural migration was net-negative (Figure 3). East Asia followed a similar pattern. However, in many regions the urban pull – rural push was not explicitly evident. Paper II revealed that both rural and urban migration in Central America was net-negative over almost the entire study period, while in

North America and Oceania both rural and urban migration were net-positive. Eastern Europe and the Middle East had the highest interannual variation in terms of net-migration ratio.

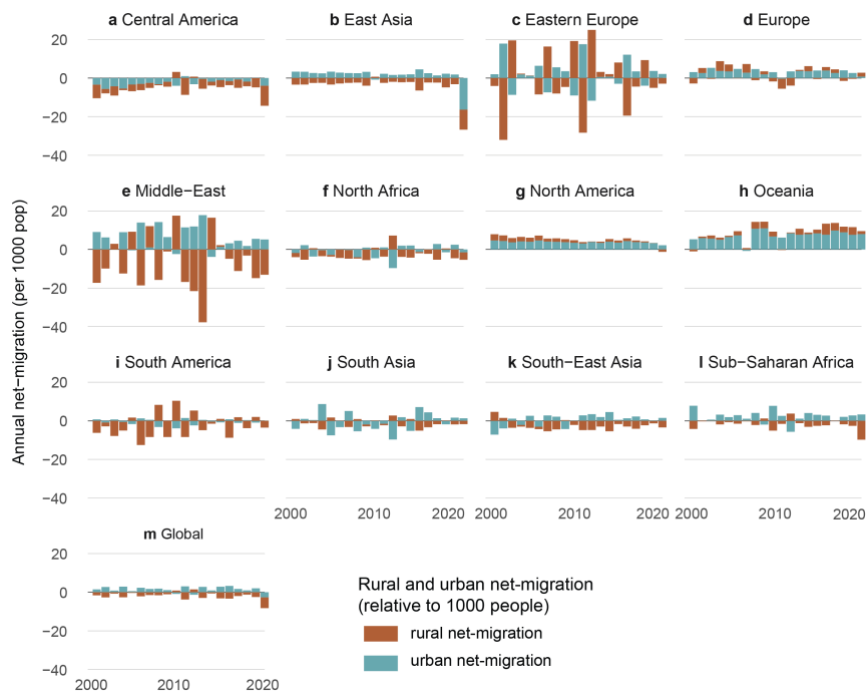
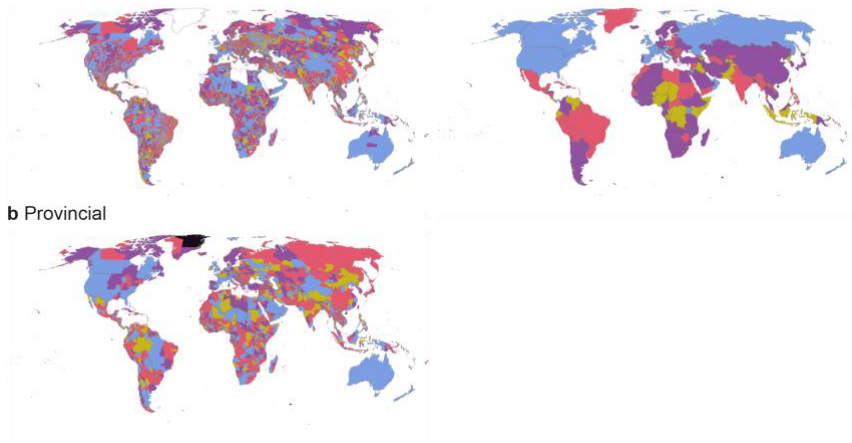


Figure 3. Annual aggregated urban and rural net-migration (per 1000 people) for 12 geographical regions and globally. (a–l) are regional sums for each year, while (m) shows the annual global sum. Regional division is based on the UN country grouping (see Figure S6 in Paper II). Modified from Paper II.

Greater variation becomes visible when looking at national and sub-national scales. Paper II revealed that almost half the global population lived in countries where net-migration was positive in urban areas and negative in rural areas. At the sub-national level, one third of global population lived in net-receiving provinces, meaning net-migration was positive in both urban and rural areas of the province, while another 30% of global population lived in net-sending provinces. This pattern becomes even stronger at communal level, where the share of global population living in net-receiving and net-sending communes was 37% and 31%, respectively (Figure 4). The results show that despite urban areas being perhaps the most important destinations of human migration, the role of rural areas as net-receiving areas is also remarkable.

a Communal

c National



b Provincial

| Division of net-migration between urban and rural areas | | | Share of population in 2019 (%) | | |
|---|-------|---------------------------|---------------------------------|------------|----------|
| Urban | Rural | | Communal | Provincial | National |
| + | + | 'net-receivers' | 37 | 28 | 12 |
| - | - | 'net-senders' | 31 | 28 | 30 |
| - | + | 'rural pull - urban push' | 18 | 19 | 14 |
| + | - | 'urban pull - rural push' | 15 | 15 | 44 |
| | | Zero migration | 0 | 0 | 0 |
| | | No data | | | |

+ Net-pos. migration - Net-neg. migration

Figure 4. Net-migration in rural and urban areas in (a) communes, (b) provinces and (c) countries. Each administrative unit was classified according to the 'direction' of urban and rural net-migration. A net-receiving province would be a province where net-migration was positive in both rural and urban areas. The table represents the share of population (in 2019) living in each category – e.g. 30% of global population lived in net-sending countries. Modified from Paper II.

4.2 Interplay and importance of environmental and societal factors

The results from Paper I and II showed that between 1990 and 2019, a significant share of global migration took place in areas with medium human development and environmental stress. From Paper I, it could be seen that during 1990-2000 around half of global migration, both net-negative and net-positive, was concentrated in areas with medium-high environmental stress and low-medium adaptive capacity. This implies that globally large numbers of migrants are leaving from and arriving to potentially vulnerable conditions. On the other hand, the highest negative and positive migration-to-population ratios were concentrated in areas with low environmental stress and low capacity and high environmental stress and high capacity, respectively (Figure 5). Only a minority of global migration took place in extreme conditions where environmental stress was high and human capacity low. This also applied to years 2000-2019: the highest net-negative migration rates took place in areas with semi-arid climate and medium-level human development, especially in rural areas (Figure 6).

Net-positive migration was clustered in high developed regions with semi-arid to arid climate, especially in urban areas. Pockets of high urban net-positive

migration rates took place in very dry regions such as the Arabian Peninsula, being one of the busiest migration destinations in the world. However, arid and temperate regions with high human development – such as those in North America, Australia, and Eastern and Northern Europe – also had high rates of net-positive migration. Paper I and II thus show with data that migration is likely used as an adaptation method in rural areas where more livelihoods are dependent on agriculture, whereas urban areas can be net-receivers even in more difficult climatic conditions.

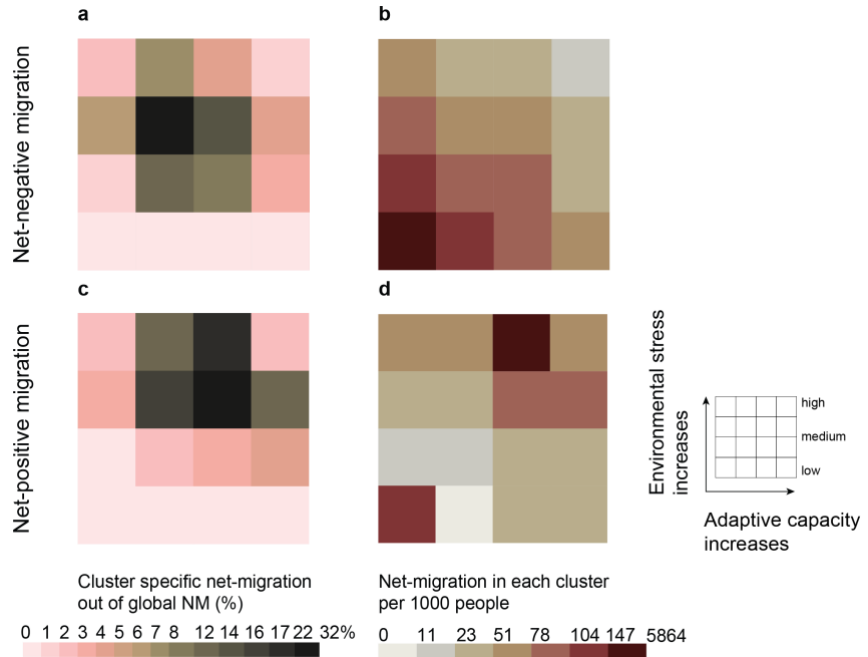


Figure 5. Percentage of positive and negative net-migration in each bin out of total global net-migration between 1990–2000 (a, c). Positive and negative net-migration (per 1000 people) in each bin (b, d). Modified from Paper I.

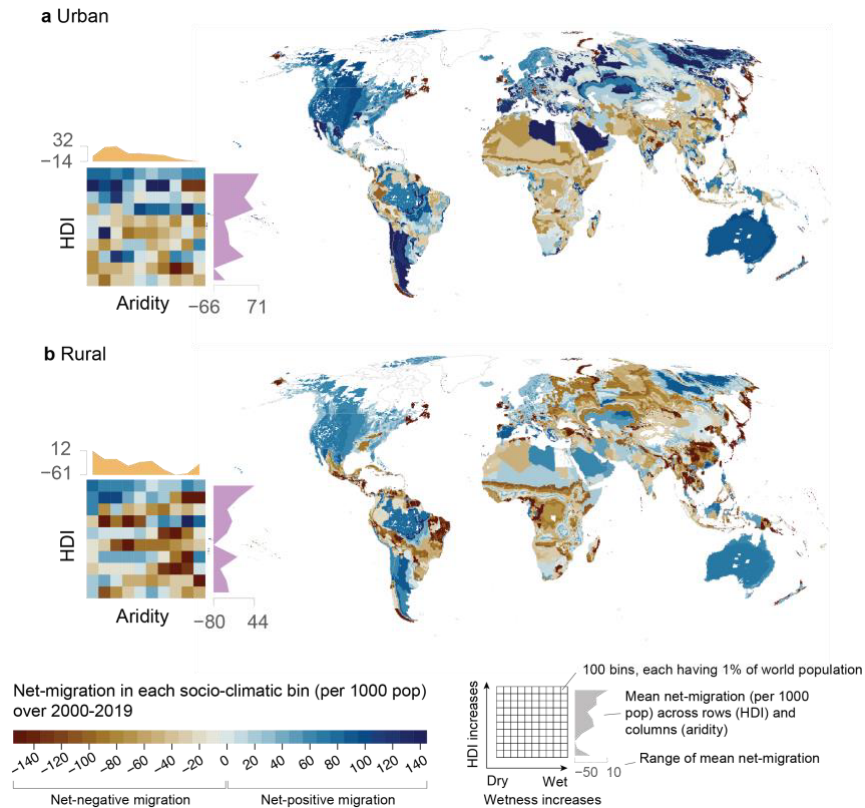


Figure 6. Urban and rural net-migration in each socio-climatic bin (e, f). Modified from Paper II.

Income ranked highest in terms of feature importance, thus portraying the highest explanatory power among individual factors explaining net-negative and net-positive migration in half of the countries in the world during 1990–2000 (Paper I). In the remaining half of the countries, education had the highest impact especially in net-negative areas. Slow-onset environmental variables – i.e., drought and water risk – were the most prominent features among environmental factors. Drought risk had a region-specific importance on both net-negative and net-positive migration, especially in the Sahel, North Africa, Central Asia, China, and Australia. The results thus provide empirical support to previous studies (e.g. Borderon et al., 2019; Hoffmann et al., 2020) suggesting that in large areas of the world, the effects of particularly slow-onset environmental factors are mediated through socio-economic factors – most commonly, income (Figure 7).

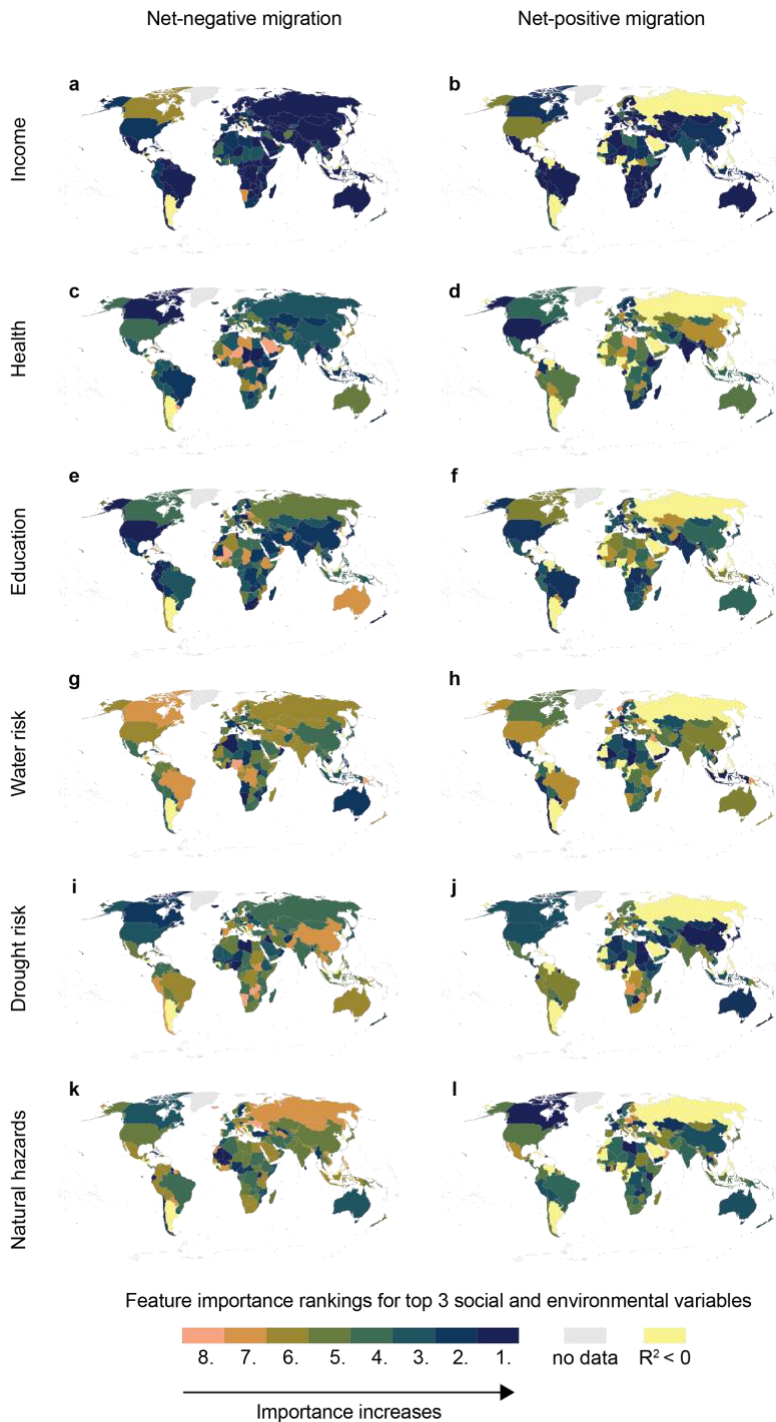


Figure 7. Feature importance rankings for top 3 social and environmental variables explaining negative net-migration (a, c, e, g, i, k), and positive net-migration (d, d, f, h, j, l). Modified from Paper I.

4.3 Implications of migration

The results showed that the negative and positive net-migration rates peak in regions with medium-level environmental stress and socio-economic conditions. High positive net-migration rates can potentially cause or increase local pressure in terms of resources and infrastructure by accelerating an already naturally growing population, or by slowing down a naturally declining population. For example, positive net-migration shifted naturally declining populations into ones of growth in the rural areas of mid-west in the USA and in Australia, for instance, whereas in Europe, parts of Russia, Central Asia, and parts of Argentina and Brazil, net-positive migration slowed down the natural decline of the population. Notably, many of the urban areas experiencing increased population growth due to positive net-migration were located in arid climates, indicating increased stress to, for instance, water resources and infrastructure in such regions (Figure 8g–h).

Both rural and urban areas impacted by positive net-migration had high human development, while negative net-migration impacted mainly areas with low human development. Notably, the results showed that urban regions impacted by positive net-migration in particular have a higher capacity to cope with the pressure on physical and social infrastructure from a growing population (Paper II). These regions include most of Europe, Russia, North America, and Australia. Yet, many urban regions in West, East and southern Africa, Arabia, as well as India, Bangladesh, China and South-East Asia experienced net-positive migration accelerating their natural population growth, with more limited capacity to cope with a growing population (Paper II).

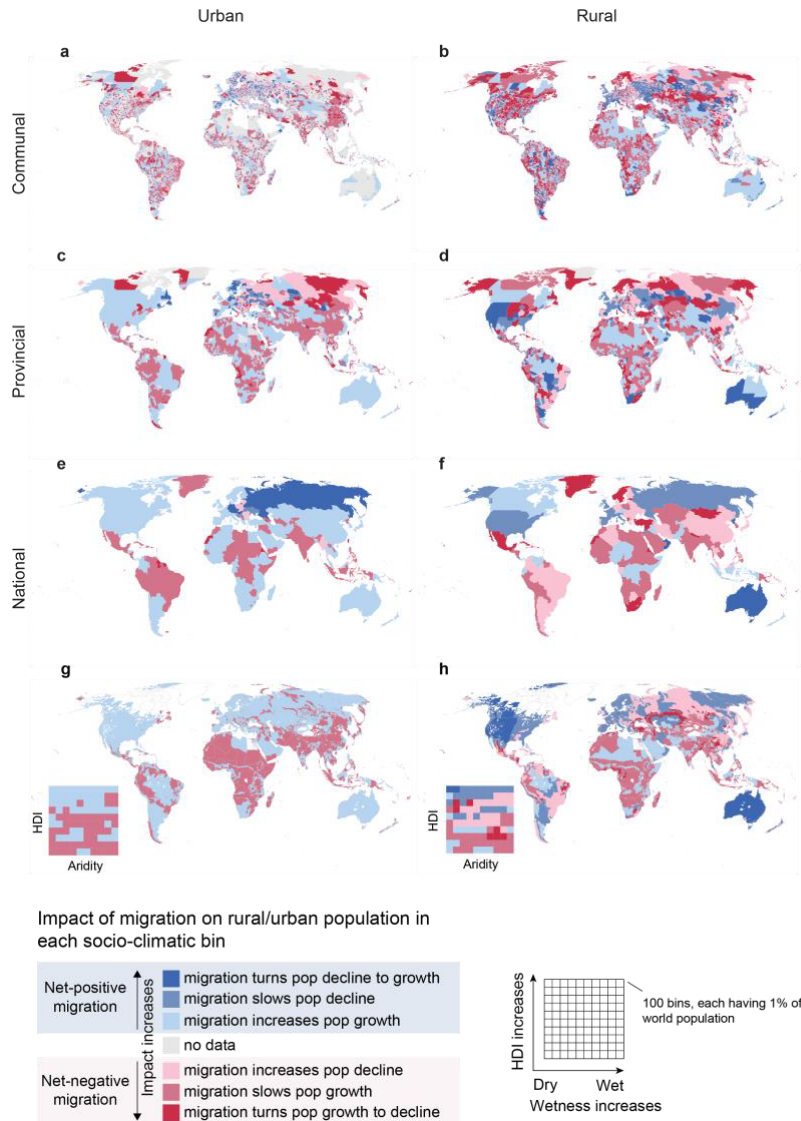


Figure 8. Impact of positive and negative net-migration on rural and urban areas at communal (a–b), provincial (c–d), national (e–f) scales, and socio-climatic bins (g–h). Modified from Paper II.

One significant implication of a situation where growing population is coupled with limited managing capacity can manifest itself through the growth of informal urban settlements (Paper III). Despite migration being an adaptation method, there are several pathways it can take (see Section 2.3). In addition to the level of generic capacities, several specific capacities impact on the outcomes of adaptation (Eakin et al., 2014) or as argued here, migration. For instance, the interplay of high generic and specific capacities – such as high HDI and effective urban management and governance in terms of migration – is more likely to lead to ‘sustainable migration’. Accordingly, a combination of low generic and specific capacities might ‘trap’ people in both urban and rural areas.

I argue that ‘unsustainable migration’ can be characterized by two combinations of generic and specific capacities (developed from Paper III). First, the individuals with sufficient specific skills to migrate are at risk of ending up in underserved and vulnerable urban or rural areas due to low system-level capacity to support the migration process through basic services, such as infrastructure. Second, it is not a given that a location with high human development would automatically result in a sustainable outcome² if specific capacities are low (Figure 9).

In some countries, restrictive migration policies can result in adverse effects at both system and individual levels. Literature has shown that policies, especially those targeted at reducing the number of refugees, often force migrants and refugees to utilize illegal arrangements for migration (McLeman, 2019), despite migration’s potential for increasing wealth in receiving countries and regions (Benveniste et al., 2021). Thus, Paper III in this dissertation shows that in order to understand the different pathways and implications of migration, quantitative analyses of the interplay between socio-economic and environmental factors of migration must be complemented with more local analyses that break down and scrutinise the interactions and balance of different factors of capacity.

² Eakin et al. (2014) define “sustainable adaptation” as “the domain of high generic and high specific capacities”. They characterize this as a pathway in which individual- and system-level capacities, such as specific skills, general human development, and policies are sufficient to produce a sustainable outcome.

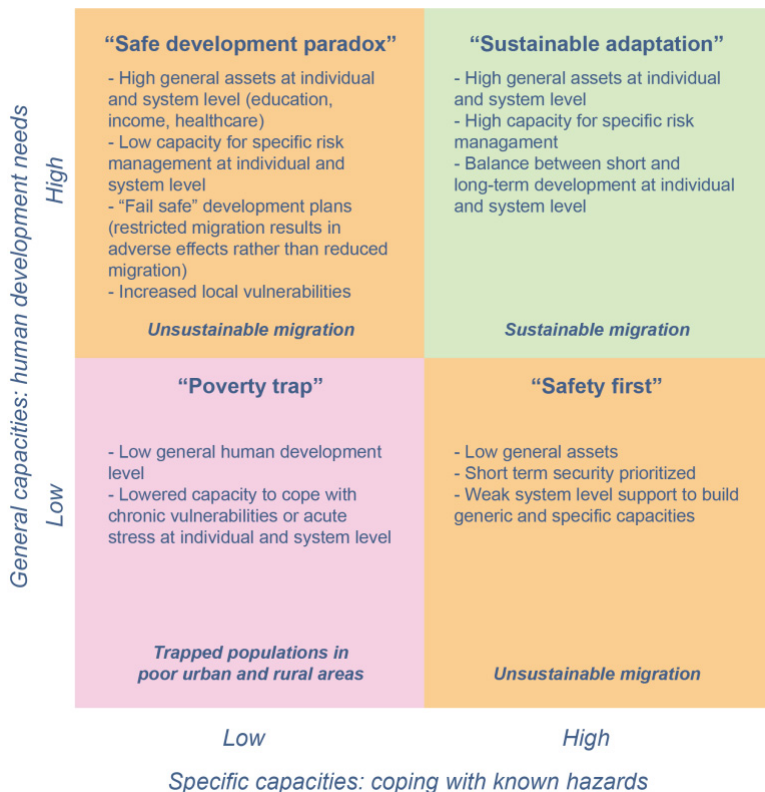


Figure 9. Interplay between general and specific capacities and four pathways of migration. Developed from Paper III.

5 Discussion

This dissertation aims to provide a data-based global synthesis of human migration and its socio-environmental factors over the past 30 years. I achieved this goal by exploring the following three research questions:

RQ1: How has global migration evolved over the past 30 years and how is the phenomenon characterized across different geospatial units?

RQ2: What are the key drivers of human migration, and how has the interplay between these drivers changed over time in the origins and destinations of migration?

RQ3: What are the implications of migration in rural and urban areas?

In this section, I summarize the new scientific findings for each research question. Then, I reflect on these findings in relation to the literature, after which I discuss the limitations and ways forward.

5.1 New scientific findings

To study the development of global human migration over the past 20 years (RQ1), I utilized a novel dataset of migration (see Methods). This dataset allowed the inspection of human migration over a 20-year period at multiple geospatial scales in both rural and urban areas at regional, national, provincial and communal levels. So far, quantitative analyses of human migration and its drivers have been conducted at a national level if a global study is in question (see e.g. Abel and Cohen, 2019; Grecequet et al., 2017), or sub-national when specific countries or regions are under scrutiny (Neumann et al., 2015; Neumann and Hermans, 2017). The quantification of urban and rural migration is rare (See e.g. Nawrotzki et al., 2017, 2015 for Mexico), while global representations do not exist. The dissertation shows that **high resolution global data is essential in detecting patterns of urban and rural net-migration as national data and analysis masks any intranational variation (Paper II)**. This finding supports previous estimates (Hoffmann et al., 2020) and future projections (McLeman, 2019) regarding the dominance of interprovincial migration over international, **highlighting the importance of high-resolution data and analysis**.

Further, despite the fact that many different drivers of human migration have been identified (Black et al., 2011b), empirical evidence regarding the role of environmental factors and their interplay with socio-economic factors in particular has been missing. In fact, there is an urgent need for data-based studies which investigate the role of the environment, not by ‘reinforcing’ the narrative of climate-migration, but by critically observing the social-environmental conditions of human migration (Boas et al., 2019). Thus, in this dissertation I utilized globally explicit datasets of migration (dataset in Paper II was partly constructed by the author), demography, as well as socio-economic and environmental factors, to study the key drivers of human migration globally. I also investigated what kind of interplay exists in relation to these drivers, and how this interplay has developed over time (RQ2). The dissertation reveals that **the majority of global migration over the whole study period between 1990–2019 took place in social-environmental conditions characterized by medium-level human capacity and environmental stress (Papers I & II). Between 1990–2000, socio-economic factors, especially income dominated in explaining net-migration over environmental factors globally (Paper I).** The findings illustrate notable variation between the world’s countries in terms of the importance of factors related to migration, as shown previously for Africa (Borderon et al., 2019).

Finally, I explored several implications of migration in rural and urban areas (RQ3). Here, global net-migration data was used to identify the conditions of rural and urban migration and their impact on population. The dissertation reveals that over the past two decades, **rural and urban areas with the highest positive net-migration had medium-to-high human development levels, indicating a high level of attractiveness and higher capacity to cope with migration (Paper II). However, the dissertation also demonstrates that high human development level alone is not enough for sustainable migration outcomes. Rather, it depends on the interplay between generic and specific capacities of individuals and systems at both ends of migration (Paper III),** as argued also by Hoffmann (2022) in a recently published article. Indeed, in previous literature it is acknowledged that many migrants are as likely to end up in similarly vulnerable environments as the ones they move away from (Black et al., 2011b). This emphasizes the need for a better understanding of what kind of factors shape the adaptation pathway and its sustainability.

5.2 Integrative approaches for understanding the complexity of human migration

In the coming years and decades, societies across the world will be increasingly influenced by unprecedented environmental change, population growth, and urbanization (Adger et al., 2020; Aerni, 2016). Millions of people will be pushed out from the climatic ‘niche’ that has so far accommodated the majority of the global population (Xu et al., 2020). The safe climatic space for growing food

(Kummu et al., 2021) will change, while water scarcity is projected to worsen at an alarming pace in the driest areas of the world (Munia et al., 2020), and excessive rainfall will flood wet areas with an even higher intensity (Caretta et al., 2022). At the same time, income levels are expected to continue growing globally (Dellink et al., 2017), while also the number of people with secondary education is expected to grow in the coming years (Roser and Ortiz-Ospina, 2016). No doubt, migration will remain an essential adaptation method in the future. Thus, integrative approaches are needed, especially in policy-making, in order to understand the full complexity of human mobility and its connections to climate, environment and sustainable development (Boas et al., 2019; Hoffmann, 2022; Hoffmann and Muttarak, 2021, 2021).

This dissertation showed that linking environmental and societal factors in examining migration is perhaps one of the most fundamental factors in building a systemic approach for migration, especially in the context of environmental change. Given that migration is ultimately a decision based on non-environmental and environmental factors (Black et al., 2011b), systems-thinking provides the means for factoring in the connections between different sub-systems (Adger, 2006). The findings of this dissertation show that the importance of environmental factors in migration was secondary in a majority of countries (Paper I), and that the impact of migration on population was more dependent on human development than climate (Paper II). This highlights the necessity of integrative approaches, especially in quantitative analyses of migration, which would allow a 'holistic understanding', thus addressing the 'interconnectedness' of different sectors, factors, and domains of migration (Thalheimer et al., 2021).

I further demonstrated that linking the conditions of migration at origins and destinations is instrumental in understanding migration outcomes. A systemic view on rural-urban migration revealed that its adverse effects in urban areas are highly dependent on rural-urban linkages regarding human capacity and environmental vulnerability (Paper III). This underlines the need to bridge rural and urban areas in the context of migration (Hoffmann and Muttarak, 2021), and also to focus on urban areas as destinations (Adger et al., 2020; Boas, 2017). Urban areas are more often impacted by positive net-migration (Paper II), increasing the pressure on both social and physical infrastructure – especially in low-income regions (Awumbila, 2017). Meanwhile, the capacity of individuals and societies play a big role in what migration looks like in the destination (Adger et al., 2021). On the other hand, migration can also slow down a declining population or turn it to growth (Paper II), which is especially crucial in aging regions such as Europe (Harper, 2012).

Hoffmann et al. (2021) suggest that policy-making should “look beyond the boundaries” defined by sub-systems within migration-urbanization-environment-nexus. Indeed, many urban and migration policies are detached from one another, making systemic and holistic policy-making challenging (Paper III), while potentially exacerbating the adverse effects of migration towards urban

areas (Tacoli et al., 2015). Thus, Paper III underlines the potential of finding synergies between different “policy domains” through leveraging cross-cutting factors, such as water. Domains crossing different sectors can assist in navigating complex systems and finding common-ground in effective policy-making (Taka et al., 2021). The identified complex interplay between environmental and social factors, between general human development and specific capabilities, and between urban and rural areas, highlights the power of adopting systemic approaches in both research and policy-making.

5.3 Limitations and ways forward

The analyses conducted in this dissertation come with limitations characteristic to all global data analyses. Firstly, both datasets of net-migration are products of modelling. The data used for Paper I contained a minor built-in error, while the data constructed for Paper II contained several sources of uncertainty. A variety of data-sources for births and deaths raises questions of consistency, reliability and comparability. The downscaling conducted to transform sub-national birth and death data into higher resolution grid is ultimately a regression modelling exercise subject to uncertainty, despite the model produced reasonably accurate predictions (R^2 being 0.6 for deaths and 0.74 for births. For details see Table S1 in Paper II). This also applies to many of the socio-economic data such as income, education and HDI, and environmental data such as water stress, drought index and aridity, which are all products of downscaling and thus prone to inaccuracies – especially in remote areas.

Second, the use of ‘net-migration’ as a measure of migration in the dissertation has several limitations. Given that net-migration only describes the difference between out-migration and in-migration, it masks any individual migration events or even the amount of out-migration and in-migration in an area. Furthermore, with net-migration it is impossible to differentiate between different types of migration (see Box 1), especially between forced and voluntary types, which need to be distinguished for policy and regulation (Martin, 2018). The data used here represents net-migration at 10km resolution grids, and thus only migration and mobility between cells are captured. This means short-distance mobility within each 10km² cell is not captured. Nevertheless, I argue it is a reasonable measure for studying human migration with annual or decadal time steps, and at global scale as done here. Estimating net-migration at 5 arc-minute resolution is feasible for assessing whether a region, be it sub-national or national, can be qualified as a net-receiver or a net-sender, or a hotspot for extensive out or in-migration.

Thirdly, the division and definition of urban and rural areas contains a source of uncertainty. In Paper II, urban areas were defined as the most densely populated areas in a country, while less densely populated areas were considered rural. Thus, peri-urban, semi-rural and other types of human settlement cannot be distinguished from the delineation used in this study. Further, Paper III does not

take a strong stance on defining urban and rural areas, as it leans on published literature and is thus subject to the diverse definitions used in a number of individual studies, leaving a lot of space for reader's interpretation. Also, given that the purpose of Paper III was to examine a situation where urban migration destinations expose migrants to vulnerable conditions, often in informal urban settlements or slums³, the framing here is quite one-dimensional. It should be noted that informal settlements vary in terms of the level urban services, and many of them provide migrants and other inhabitants with new jobs and forms of income (Satterthwaite et al., 2020; Tacoli et al., 2015).

Despite these limitations, the analyses and data constructed in the dissertation provide an opening for further analyses regarding the quantification and conceptualization of human migration and its drivers in urban and rural areas globally. However, while the strength of the global synthesis carried out in this dissertation is in showing regional differences and characteristics through data that are globally comparable, it should be noted that it lacks the nuance and detail of local qualitative data – for instance, as gathered through surveys, focus groups and interviews (Boas et al., 2020). Thus, the analysis of short-distance mobility, interannual variability of migration and its drivers, and localized analyses taking into account specific characteristics of migration rather than 'global' parameters as done in this study, could be of specific interest for future research. Finally, as the role of urban areas will highlight in the future in terms of climate change but also other megatrends, further analysis of the conditions and urban drivers of migration are highly relevant.

³ The term slum is used to describe a form of informal settlement defined by (typically poor) "housing quality, overcrowding, and the provision of urban services". More generally informal settlements are urban areas which "develop outside the legal systems" regarding safe land tenure and urban planning (Satterthwaite et al., 2020). The term slum is widely used in global agendas such as the New Urban Agenda and the Sustainable Development Goals.

6 Conclusions

Over centuries and millennia, people have been on the move and have migrated in order to respond and adapt to changing living conditions. With a changing climate, stressed environment, and the world's current geopolitical situation, human migration will no doubt remain an essential adaptation method. However, the future of migration looks different than it has been before. As urbanization accelerates, an increasing number of people will be moving to cities. There, new migrants face environmental and social conditions that potentially present themselves with, albeit largely different but often equally intense, vulnerabilities as in the place of origin. Thus, in order to understand the future pathways of human migration, it is imperative to understand where and in what kind of places migration has occurred, and what has shaped the outcomes of migration in the past.

This dissertation extends and improves the knowledge of human migration, its drivers, and implications by providing a global synthesis of the past three decades. This is done with a combination of quantitative gridded geospatial analysis, and qualitative literature review for the study period 1990–2019. The dissertation reveals that during this period, the majority of human migration took place in areas with medium-level human development and environmental stress, while also showing that income, education and health played a more important role than environmental changes in explaining migration. This highlights the underlying importance, but thus far often underrepresentation, of societal dimensions in the study of human migration in an environmental context. However, the dissertation also shows that in addition to general human development, specific capacity of migrants to access social networks to gain understanding of the destination, and the societal capacity to create policies that support rather than cripple the migration process, are vital in creating sustainable adaptation pathways. Indeed, the dissertation shows that over recent decades, many urban areas accommodating high rates of in-migration were located in potentially vulnerable areas in terms of climate and society. The dissertation equally underlines the importance and analytic power of combining quantitative geospatial analysis with theoretical and empirical framings offered by existing, rich scientific literature on migration, which still largely lacks global-scale spatial quantification.

Finally, this dissertation demonstrates that the patterns of migration, its drivers, and implications are remarkably different in different parts of the world. Integrative approaches connecting not only destinations and origins and urban and rural areas, but also the different domains and sectors crossing human migration and its drivers, are thus urgently needed to gain a more comprehensive understanding of the complexity of human migration.

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