# Quantifying the Evidence on Environmental Migration: A Meta-Analysis on Country-Level Studies

Roman Hoffmann[1], Anna Dimitrova[2], Raya Muttarak[3 4], Jesus Crespo Cuaresma[2,3], Jonas Peisker

[1] Wittgenstein Centre for Demography and Global Human Capital (IIASA, VID/ÖAW, WU), Vienna Institute of Demography/Austrian Academy of Sciences

[2] Wittgenstein Centre for Demography and Global Human Capital (IIASA, VID/ÖAW, WU), Vienna University of Economics and Business

[3] Wittgenstein Centre for Demography and Global Human Capital (IIASA, VID/ÖAW, WU), International Institute for Applied Systems Analysis (IIASA), Laxenburg

[4] School of International Development, University of East Anglia

## Abstract

That climate change may trigger large-scale human migration has attracted strong interest from the media, policy makers and the wider public in the past couple of years. At the same time, improved data availability and advanced computing technologies have resulted in a rapidly growing number of quantitative studies on climate and human migration. However, to date, the statistical evidence on how and under what conditions climatic factors influence population movements is mixed, making it difficult to forecast how population migration will look like under future climate change. To this end, this study aims to quantitatively synthesize the relationship between climate and human migration using a meta-analysis approach. The estimation is based on 32 comparable macro-level studies (1,800 distinct climate effects) using country-level data. Employing an innovative standardization approach, we harmonize migration estimates across studies. Besides average effects, we investigate the heterogeneity in effects across study lines considering in particular the role of non-environmental contextual factors and different theoretical mechanisms in influencing human mobility. This allows us to not only determine the scale and scope of the relationship, but to also study under which conditions environmental migration most likely occurs and why.

## Keywords

Climate change, environmental migration, meta-analysis, review, contextual factors, mechanisms

# 1 Introduction

Increased levels of greenhouse gas emission are likely to exacerbate both the frequency and intensity of extreme weather events and graduate processes of environmental degradation which pose serious threats to food security, health and water availability in many parts of the world (Hunter & Nawrotzki 2016). The populations of poorer countries are particularly affected by these developments as they depend in large parts on agriculture and have little access to technological and infrastructural means to prevent and moderate adverse environmental impacts. One possible strategy to cope with and adapt to the changes is migration. Individuals or households may decide to temporarily or permanently relocate to avert the negative consequences of environmental shocks and long-term changes (Nawrotzki et al. 2013; McLeman & Smit 2006).

That climate change will trigger large-scale (involuntary) human migration has been predicted by many scholars and UN agencies since the 1980s and there has been growing interest in the subject by researchers, policy makers, and the wider public. In the past years, research on the environment-migration nexus has proliferated with an increasing number of quantitative studies estimating the impact of (long-term or abrupt) environmental changes on migration. In particular between 2014 and 2017, the increase in the numbers of studies has been particularly sharp (see Figure A1 in the appendix). This trend reflects an increasing data availability (both climate and migration data) as well as improvements of technical and computation tools for data analysis (Fussell et al. 2014).

Although the majority of studies agree that environmental conditions are relevant for population mobility, empirical knowledge in the field remains varied, patchy, and limited (Hunter et al. 2015). Across and even within studies, the size and even the direction of the estimated coefficients largely differ depending on the environmental factors considered, the data and measures used, and the estimation methods employed. For instance, on the one hand, it has been reported that internal migration increases with a decline in precipitation, such as in rural Ethiopia (Gray & Mueller 2012), Tanzania (Afifi et al. 2014) and Ecuador (Gray 2009). Similarly, other studies have found that the availability of natural resources as measured by the greenness of vegetation or good rainfall facilitate temporary outmigration in South Africa (Hunter et al. 2014) and internal labor-related moves by men in Kenya (Gray & Wise 2016). Other set of studies meanwhile reported no consistent robust effect of rainfall on internal migration in Pakistan (Mueller et al. 2014) and in the Philippines (Bohra-Mishra et al. 2017). Given that most studies have been carried out in a localized context, it is often difficult to generalize the findings beyond the particular country or region analyzed. In many cases, we still lack a good understanding for the relevant factors on the ground which cause the heterogeneity in the findings (for a conceptual illustration of theoretical mechanisms see Figure A2 in the appendix as presented in Black et al. (2011)).

To this end, this study aims to contribute to the literature by reviewing and synthesizing the rapidly growing literature on the link between climate and migration using techniques of *meta-analysis* (Borenstein et al. 2009; Sterne 2009). This method does not only allow us to qualitatively assess the pattern of the relationship, but also to quantify its strength and to analyze differences in effect sizes and directions in various contexts. Aside of qualitative review articles on the topic (Hunter et al. 2015; Fussell et al. 2014), there is a recent study by Beine & Jeusette (2018), who conduct a meta-analysis based on previous studies in the literature. While the authors focus on *whether* previous research has found a positive or a negative effect, our approach collects information about the coefficients allowing us in addition to determine the *strength* of the relationship between the environment and human mobility. Besides estimating the average climate effect size, we study heterogeneities across study lines. In particular, we explore to what extent the effects depend on study line characteristics (e.g. the climatic factors considered or the form of mobility studied – internal vs. international) and contextual characteristics of the affected region (e.g. wealth level and agricultural dependence). Finally, by considering variations in the specification of the estimated models, we are able to also explore some of the mechanisms, which were proposed in the literature as mediators explaining reported climate effects: climate-induced income shocks, conflict, and increased population pressures and urbanization. We hence also provide theoretically relevant insights in the phenomenon.

We focus on macro empirical studies using country-level data, which are comparable in terms of research designs and data used. Commonly these studies estimate the effect of climatic variations or shocks on international and internal (proxied with urbanization) migration rates using linear models. While the coefficients of these models are comparable in terms of outcomes (0-1 bound rates) and specification (linear), different climate measures are used making a direct comparison of the estimates impossible. We overcome this challenge by standardizing the coefficients using information on the standard deviations of the climate variables, which we re-calculate for most of the considered studies using the original data. In total, we build on the evidence from *32 country level studies* on climate-related migration with more than 1800 separable study lines (individual coefficients).

The remainder of the paper is structured as follows. Section 2 introduces the meta-analytical approach and presents the standardization techniques used to make coefficients comparable across study lines. Section 3 presents our estimation strategy and elaborates on the key aspects considered in our analysis. Section 4 shows preliminary findings of our analysis and Section 5 concluded with a brief outlook to our next steps.

# 2 Data and Methods

## 2.1 Meta-Analysis Approach

Meta-analysis methods synthesize the evidence from quantitative studies and thus allow for a unified and comprehensive interpretation of existing findings while controlling for between-study differences. While meta-analysis has been widely used in the medical science and epidemiology, it only recently became more popular in the social sciences. Specifically, in the context of climate change, a study by Hsiang et al. (2013) investigates and quantifies the impacts of climate variability on conflict (see also Burke et al. (2015) or Challinor et al. (2014)). Since meta-analysis aims to derive a unified, pooled estimate from different studies in form of a weighted average, the key benefit of the approach is the aggregation of complex information leading to higher statistical power and more precise estimates (Borenstein et al. 2010; Lipsey & Wilson 2001). Besides estimating average effect sizes, it is possible to study heterogeneities using meta-regression techniques.

Meta-analyses include several steps (see Figure 1) starting with an extensive and systematic search for quantitative studies (section 2.2). Based on certain incorporation criteria, a sub-set of studies is selected in a second step. Key statistics (e.g. coefficients, standard errors, confidence intervals) are then derived from each study. Given that the measurement of key variables is different for each study, coefficients need to be harmonized before the actual analysis (section 2.3.). In our estimation, we employ random effects meta-regression models (section 2.4), which allow us to flexibly estimate the relationships of interest and to take differences between studies into account.

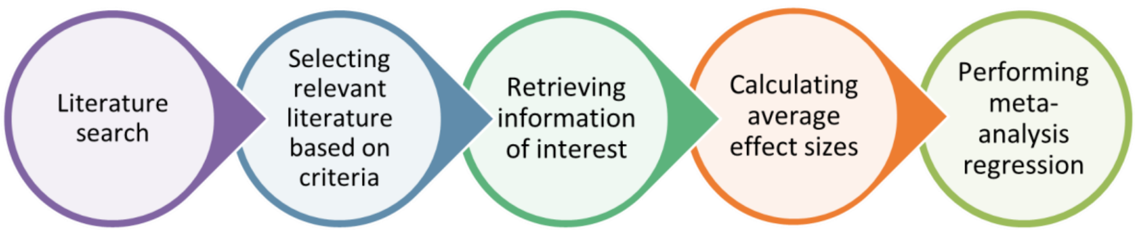


Figure 1 – Steps in meta-analysis

Throughout the meta-analysis process, various challenges can arise, such as the ignorance of grey literature ('file drawer problem') in the selection stage or issues with the data generation (e.g. standardization of coefficients). To account for these challenges we employ various statistical tools (e.g. funnel plots, Egger tests) and document the different steps and assumptions made in the process in a comprehensive and transparent way (detailed supplementary material will be provided).

## 2.2 Literature Search and Selection of Studies

We started with a broad search for quantitative empirical studies (both micro and macro) to get an overview of the research field. The literature search included journal articles, book chapters, books and working papers. It relied on both online resources, scientific database (e.g. Web of Science, Scopus, ScienceDirect, Wiley Online Library, Google Scholar) and references provided in the papers. Citation tools were used to identify relevant working papers and grey literature.

Our initial search resulted in more than 150 studies that statistically analyzed the relationship between climate-related factors and some forms of human mobility. By environmental migration, we define any impact from environmental conditions, such as weather variability or natural disasters, on migration decisions, either directly or indirectly through other channels. In our analysis we thus take both long-term climatic changes as well as short-term events into consideration. We selected only articles published in English language after the year 2000. To ensure that we have thoroughly located relevant literature, we crosscheck with the CLIMIG Database, a comprehensive bibliographic collection of resources on migration, the environment and climate change (IOM 2012). Furthermore, we are currently contacting experts in the field to evaluate the completeness of our initial search and to add undetected materials.

In a second step, we subdivided the initial set of studies into different groups and made a preliminary selection based on research focus of the study and quality. There is a natural trade-off between homogeneity in the measurement of key variables (the less variation, the more meaningful the meta-analysis is) and the inclusion of a broad enough (and representative) subset of eligible studies. Mainly, we focus on quantitative studies that can reliably infer causal associations between environmental variables and migration through exploiting variations in environmental variables over time.

Furthermore, in our analysis we focus on studies that use macro data analyzing the impact of environmental conditions on country-level migration rates (bound from 0-1). Although with this approach we may arguably miss important aspects of climate-related migration at the micro-level (e.g. on the role of household characteristics, regional contextual influences, etc.), it has several important advantages. By focusing on country-level studies, we can ensure that coefficient estimates are sufficiently comparable to each other as the majority of these studies uses similar estimation methods, specifications, and measurements. Furthermore, in order to harmonize coefficients from different models, detailed summary statistics for climate and migration variables are required. These can be more easily retrieved for country-level data than for more idiosyncratic micro or individual-level survey data. Based on our selection criteria, in total, 32 studies are included for the analysis of climate effects on both international and internal migration (for an overview see Table 1 in the appendix).

## 2.3 Standardization of Coefficients and Interpretation

Macro studies on the relationship between climate and migration tend to base their estimates on linear regression models of the following specification:

$$M_{jt} = \alpha + C_{jt}\beta + X_{jt}\gamma + \theta_j + \tau_t + \epsilon_{jt} \tag{1}$$

with the outcome variable $M_{jt}$ representing the migration outcome in country *j* at time *t* (which is usually measured in decade intervals). Commonly studies consider net migration rates (or a transformed equivalent of this measure) as main variable of interest. $C_{jt}$ on the right-hand side of the equation captures the climate-related measure(s), such as the degree or variability of precipitation, temperature or a short-term disaster shock. $X_{jt}$ is a matrix of variables explaining the remaining differences in the outcome, and $\theta_j, \tau_t,$ and $\epsilon_{it}$ represent country specific, time specific and random error terms. A slight variation of the above model are gravity-type models which take a dyadic form and consider both characteristics of the origin and destination countries (Beine et al. 2016).

In our meta-analysis we are interested in the vector of coefficients $\beta$. Note that single studies usually estimate more than one coefficient to capture the influence of various climate measures or to test for the robustness of the results. In our analysis, we consider each estimate as a separate *study line* correcting our meta-coefficients and standard errors for study fixed effects. The main challenge of our analytical approach is to make coefficients $\beta_{im}$ comparable across study lines.

These cannot be easily compared as the climate and environmental measures on the right-hand side of the equation capture different climatic influences, which are measured and scaled differently. For instance, while some studies consider coefficients of variation (e.g. of precipitation), others study the effect of level differences or anomalies in their specifications. However, meta-regressions require that coefficients share the same metric and interpretation.

To standardize the coefficients and standard errors, we use information on the standard deviations of the climate and migration measures, which we retrieved from the original data, which was either shared with us by the authors or retrieved online. The standardization of the coefficients and standard errors takes the following general form:

$$\beta_{stan} = \beta_{im} \cdot \frac{\sigma_C}{\sigma_M} \tag{2.1}$$

$$SE_{stan} = SE_{\beta_{im}} \cdot \frac{\sigma_C}{\sigma_M} \tag{2.2}$$

With this procedure, we can eliminate any particularities in the measurement and scaling of the explanatory measures. The resulting standardized coefficients can be interpreted as standard deviation changes in the migration outcome by one standard deviation change in the climate input variable. Note that here we abstract from the different type of climatic influences. However, in the meta-regressions (3) we control for the type of climatic effects underlying the respective study line in order to better comprehend how different climatic influences may affect populations differently.

Several studies estimate coefficients for sub-samples of countries, such as poor vs more wealthy and agriculturally dependent vs less dependent countries. By exploiting this information, we can learn important lessons about the relationship between the environment and migration in different contexts. In addition to using information from coefficients, which were estimated for sub-samples, we also include coefficients, which are based on interaction terms. Several studies interact environmental variables with contextual information similar to the one used to construct sub-samples, i.e. the wealth level or agricultural dependence of the origin country. To use this information, we decompose the interaction effects into different coefficients for the sub-samples. In our meta-regressions, we control for the composition of the samples used in the models and test for the effects of contextual factors. For the standardization, we use the standard deviation in the sub groups for which we calculate the separate effects.

## 2.4 Meta-Regressions

Our meta-regressions are based on the following equation (Crespo Cuaresma et al. (2014):

$$\beta_{stan,im} = \mu + D_{im}\delta + u_{im} \tag{3}$$

Where $\beta_{im}$ is the standardized coefficient estimate corresponding to study line *i* in study *m* and *D* is a matrix of study-line specific covariates that are of interest in the analysis. For instance, *D* captures the aforementioned contextual factors, such as the agricultural dependence or wealth of the sample considered in a study line. We also include a quality score in the meta-regressions to control for the effect of differences in study quality on effect sizes and directions. Furthermore, we add measures for the most commonly used controls in the models to take the degree of sophistication of the model into account.

## 3 Estimation Strategy: Explaining Differences in Climate Effects

In the first step of our analysis, we estimate average environmental effects on migration across all study lines in order to determine to what extent, overall, environmental influences matter for migration. In the second step, we are interested in exploring and explaining remaining heterogeneities across study lines in our meta-regressions using information about (i) study line features, (ii) composition of the considered samples, (iii) and theoretical channels controlled for in the considered models (see Figure 2).

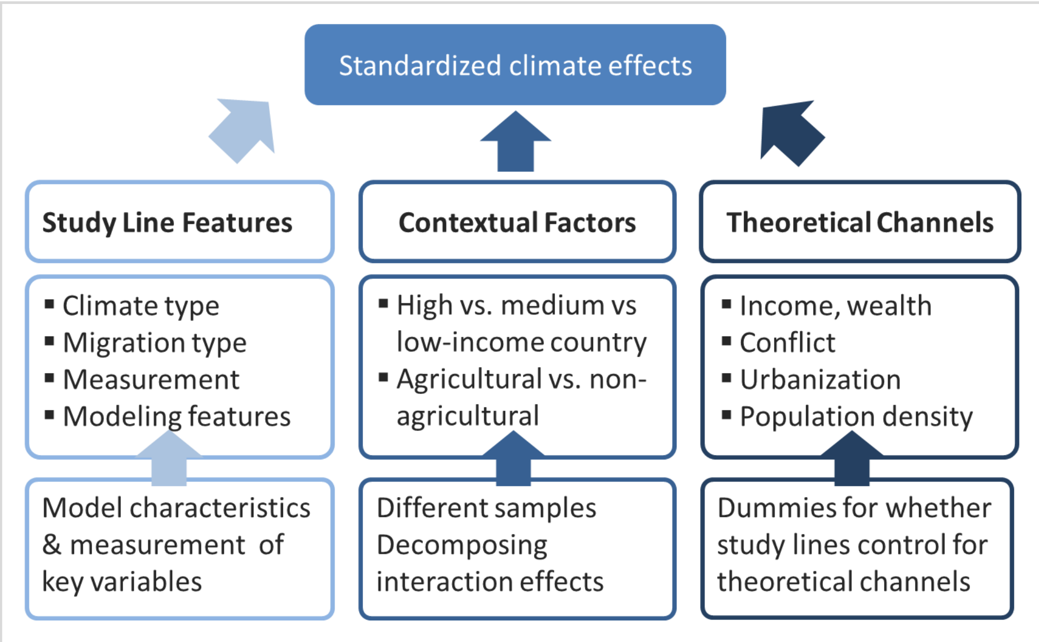


Figure 2 – Explaining differences in climate effects across study-lines

As a first group of explanatory variables, we include information about the study lines in our meta-regressions. In particular, we are interested in how different types of environmental shocks affect mobility differently and whether environmental effects are generally stronger for internal or international migration. In addition, we test for the importance of measurement and modeling features, which we derive directly from the study line tables in the papers, such as whether the study lines uses fixed effects and interactions. To avoid publication biases in our analysis (Rothstein et al. 2006), we included both published and unpublished work, such as working papers and mimeos. In our meta-regressions, we control for whether a study line was derived from a published article or not and the impact factor of the journal.

As described above, we are moreover able to distinguish coefficients by different sub-samples. Studies commonly calculate separate effects for sub-samples of countries with different levels of wealth and agricultural dependence. However, studies use very different ways to classify countries and to form the sub-samples, making it difficult to compare the coefficients and to control for the contextual factors considered. To solve this issue, we focus on the composition of the samples used, i.e. the countries included in the samples, which we categorize according to our own classification. We can then calculate the share of countries for each (sub-) sample, which fall into a specific category, such as low or high-income countries, agriculturally dependent countries, or countries in Sub-Saharan Africa.

Our meta-data set consists of 110 different (sub-) samples. We use the World Bank classification for the year 2002, which is the median year, when most panels of the considered study lines end. First, we obtain the share of countries, which are either low-income, lower-middle, upper-middle, or high-income; second, we calculate the percent of agriculturally dependent countries in the sample, i.e. countries whose agricultural share in GDP is in the top quartile of all countries; and third, we calculate for each sub-sample the share of countries that belong to different regions: Sub-Saharan Africa (SSA), Latin America and Caribbean (LAC), Middle East and North Africa (MENA), Europe and Central Asia and North America, and South, East, and Southeast Asia. In total, we derive ten compositional variables (Figure 3), which we include in the meta-regression models to test for differences in effect sizes by different sample compositions.

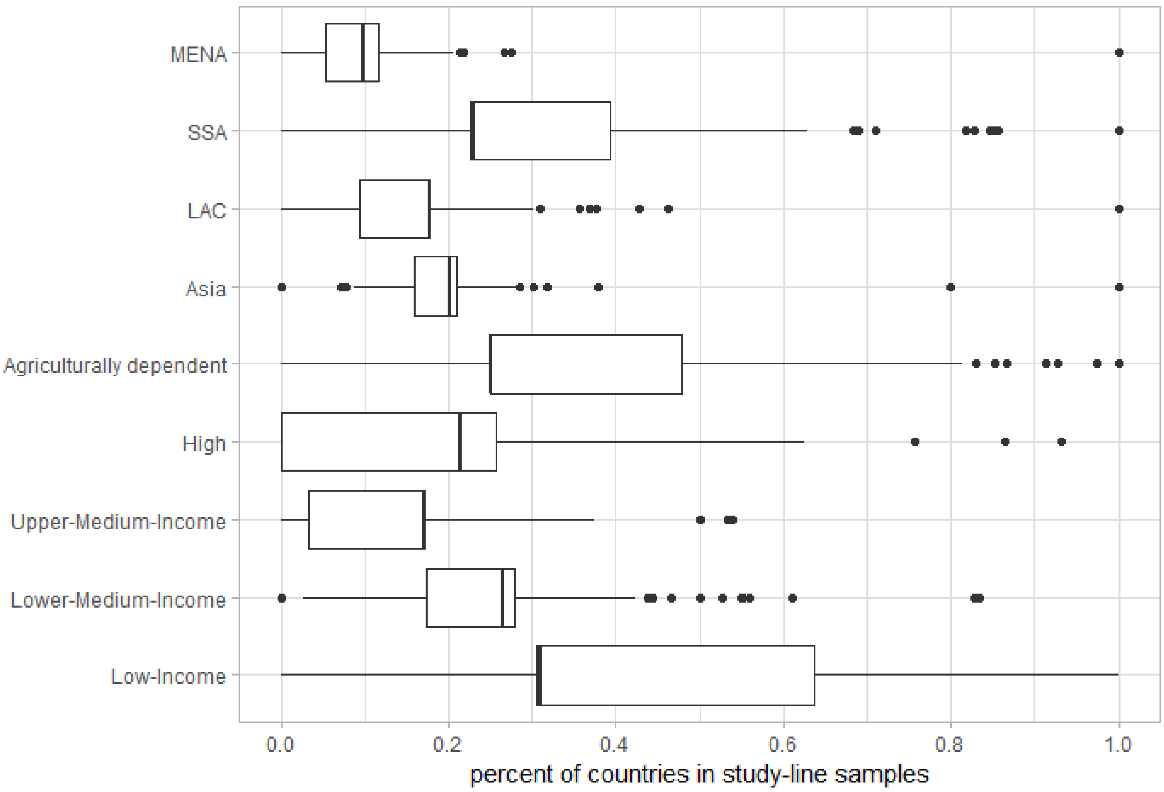


Figure 3 – Percentage of countries in study line samples by classification category

Distinguishing study lines by wealth level and agricultural dependence allows us to test two central hypotheses in the climate-migration literature. First, we test for the importance of the *agricultural channel*. Previous research has suggested that countries, which are more dependent on agriculture (in their income earning and sustenance), should be stronger affected by adverse climatic changes and should hence show a stronger migratory response (Cai et al. 2016; Schlenker & Lobell 2010; Mendelsohn & Dinar 1999; Dethier & Effenberger 2012). Second, we consider the moderating effect of country wealth level on the migration effect. Adverse climatic shocks and changes may lead to a significant reduction in (agricultural) income. As a consequence, poorer households may lack the resources necessary to finance their mobility which may trap them in place and hence lead to a negative effect on migration (Black et al. 2011; Henry et al. 2004; Nawrotzki & Bakhtsiyarava 2016). We test for this so called *climate inhibitor mechanism* by analyzing differences in the climate-migration relationship between poor and wealthier countries as identified by the studies. Figure 3 shows the distribution of study lines focusing on countries with different levels of agricultural dependence and wealth level.

Finally, we estimate the importance of different theoretical channels by making use of an innovative approach. Based on the literature, we identified the four main theoretical channels through which the environment is expected to have an impact on human mobility: Income shocks, conflict, population density and urbanization. We assessed whether the encoded study line models controlled for any of these potential mechanisms, such as by including GDP per capita or a war or conflict measure in their estimation. We then created four dummies, which take the value one if the mechanism is controlled for in the model and zero otherwise. If the respective included factor represents a relevant theoretical mechanism, we expect it to explain part of the (hypothetical) total environmental effect, which means we expect the reported effect to be smaller than in a model, which does not control for the mediating mechanism (see Breen et al. 2013 or Hoffmann & Muttarak 2017 for a discussion of the mediation argument). By analyzing the variation in control variables across study lines, we can hence infer some suggestive evidence about potential linking mechanisms, which explain how climatic factors influence migration. [1] If a variable represents a theoretically relevant mediator, we expect climate effect sizes to be on average lower if this factor was controlled for in the model.

Figure 4 shows the percentage of studies, which control for one of the potential mediating factors. Clearly, many of them include one or another of the factors. Most commonly studies include a measure for income or wealth as controls in their models.

[1] In the terminology of Angrist & Pischke (2009), the inclusion of mediators/mechanisms and the resulting downward biases in the estimation of the total effect represents a 'bad control' problem, if the paper's goal was to estimate total climate effects (see also the discussion in Burke et al. 2015). By comparing different study lines and variations in the model specifications, our approach makes use of this inclusion of potential mediation in the specifications to infer information about possible theoretical explanations of climate effects.

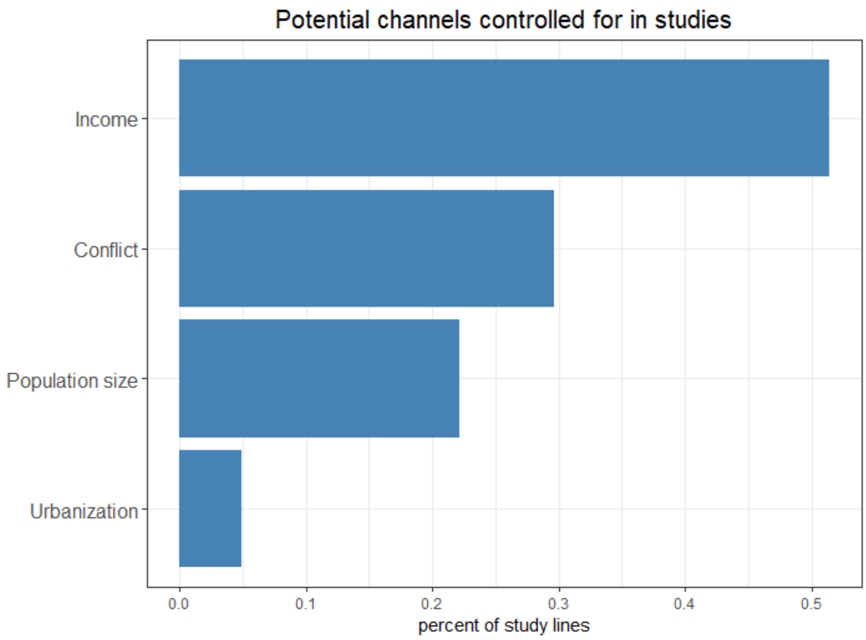


Figure 4 – Percentage of study lines controlling for theoretical mechanisms

# 4 Preliminary Findings

## 4.1 Qualitative Review

Table 1 gives an overview of the results of the macro studies which form the basis for our meta-analysis. The majority of studies analyze the effect of temperature and precipitation changes on migration. Both factors are considered in 17 studies. Short-term hydrological (floods, mass movement and landslides, avalanches, subsidence), meteorological (tropical storms, cyclones, local/convective storms), and climatological disasters (extreme temperature, drought, and wild fire) are considered in 11 studies. Several studies estimate the effect of different climate-related influences simultaneously acknowledging that they may depend on each other (Marchiori et al. 2017)

Out of the 32 reviewed studies, 28 find a significant correlation between climatic conditions and population mobility, either internal or international, clearly highlighting the role of migration as an adaption strategy to environmental changes (Ruyssen & Rayp 2014; Gröschl & Steinwachs 2016). However, the size and the direction of the reported effects varies substantially across study lines depending on the exact measurement and estimation procedures. Earlier studies were mostly focused on the identification of the overall climate effects on migration, suggesting that climate shocks and adverse changes have a primarily positive effect on migration (Rowlands 2004; Barrios et al. 2006; Naudé 2008; Afifi & Warner 2008; Reuveny & Moore 2009; Alexeev et al. 2011; Martinez-Zarzoso et al. 2012)

Recent studies increasingly started to take heterogeneities in climate effects into consideration revealing the important role of the context in shaping migration decisions and household constraints. Although some ambiguities remain, these studies clearly show that the specific study context plays an important role. The environment-migration link is strongly shaped by cultural, geographical, institutional, and socio-economic factors in the origin countries, which explain some of the differences across studies (Grecequet et al. 2017).

While most studies focus primarily on international migration, a few do also consider internal migration (n=9), which is mostly captured in form of the urbanization rate in the country. When analyzing international migration streams, it is important to take population movements within countries into account as people tend to move first to locations in close proximity of their origin regions (Hunter et al. 2015). In this regard, urban agglomerations represent preferred destinations of migrants who are looking for additional income earning opportunities, which also offer them and their families a way to diversify from climate dependent income sources. The increased movement towards cities can subsequently lead to increased pressure on labor markets and wages, which in turn can spark (potentially international) out-migration (Marchiori et al. 2017; Maurel & Tuccio 2016; Cattaneo & Peri 2016; Beine & Parsons 2015). Interestingly, these migrants do not necessarily have to be the people who were initially migrating because of adverse climatic-conditions. Hence migration for environmental and economic reasons are closely related (McLeman & Smit 2006).

There is convincing evidence showing a stronger effect of environmental conditions on migration decisions on more *agriculturally dependent countries* which may result from their higher vulnerability to climatic change (Marchiori et al. 2012; Marchiori et al. 2017; Coniglio & Pesce 2015). For instance, Cai et al. (2016) report stronger migration responses to increased precipitation in countries with a large agricultural sector. Similar results are presented by Backhaus et al. (2015) and Aburn & Wesselbaum (2017) for the impacts of disasters. The macro evidence is supported by various micro-level studies that focus particularly on rural populations revealing their higher susceptibility to the negative impact of environmental shocks and changes (Hunter 2005; Afifi 2011; McLeman & Smit 2006). At the same time, few studies find a negative or ambiguous effect of climatic changes on agriculturally more dependent countries. For instance, Cattaneo & Peri (2016) find a negative effect of temperature on internal and international migration in agricultural countries; and Marchiori et al. ( 2017) find that while higher temperature lead to higher urbanization in agricultural countries, a reversed effect is estimated for international migration.

Across studies *wealth level* is found to be an important moderator of climate effects. Some studies find support for the notion of climate-induced poverty traps, which prevent poorer people from migrating due to lack of resources. Interacting precipitation and temperature measures with country wealth levels, Cattaneo & Peri (2016) report a strong migration response to increasing temperatures in middle-income countries whereas there is a reversed negative effect for poor countries suggesting that these populations may suffer existential income losses due to climatic shocks preventing them from migrating (see also Peri et al. 2016). Also, Drabo & Mbaye (2015) find a positive effect of disasters on international migration only for countries with a high share of highly educated (as a proxy for wealth) suggesting that they can afford the migration costs (see also Hanson & McIntosh 2012). However, the findings are not consistent across studies. Aburn &

Wesselbaum (2017), on the other hand, find stronger migration responses to temperature and rainfall shocks in poorer, agricultural countries. Similarly, Maurel & Tuccio (2016), Bettin & Nicolli (2012), and Coniglio & Pesce (2015) find stronger environmental influences on population movements in poorer, less developed compared to wealthier countries which may be due to a higher exposure of these countries to adverse climatic conditions making households more likely to migrate.

One explanation for the diversity of findings is that many studies are not properly able to account for short-distance moves, especially of poorer households who may lack the resources required for international migration, but may instead choose to move to a destination in close proximity of their origins (Obokata et al. 2014; Afifi 2011). Differences in measurement and conceptualization of key measures offer another explanation for some of the discrepancies in the findings. As has among others been emphasized by Piguet (2010) and Warner (2011), there is a need for a more coherent framework in how to conceptualize and measure climate-related migration flows.

Environmental migration is a complex phenomenon which is strongly linked with contextual, non-environmental factors. Sometimes it is the lacking capability to cope with the consequences of climatic changes that make households decide to migrate (Alscher 2011; Wrathall 2012). The review shows the complex linkages between environmental and non-environmental factors and strongly suggests that migration outcomes are highly context specific (Obokata et al. 2014). With our meta-analysis we attempt to add some quantitative insights on how such contextual factors shape migration and how a better understanding of these factors can help to explain some differences in findings across studies.

Table 1 – Overview of country-level studies on environmental migration

| Study | Period | Sample (N) | Env. | Migration | Heterogeneity | Main Findings |
|---|---|---|---|---|---|---|
| Abel et al. (2019) | 2006-2015 | World (157) | T, P | M | - | Climatic conditions affect drought severity and the likelihood for armed conflict, which in turn has significant effect on migration |
| Spencer & Urquhart (2018) | 1989-2005 | LAC (30) | D | M | - | Hurricanes have a positive impact on migration. Impact is greater for more damaging storms. Strong context dependence |
| Marchiori et al (2017) | 1960-2000 | SSA (39) | T, P | U, M | A | T $\xrightarrow{-}$ U, T $\xrightarrow{+}$ M for non-agricultural c.<br>T $\xrightarrow{+}$ U, T $\xrightarrow{-}$ M for agricultural c.<br>Level of income more important than variability |
| Beine & Parsons (2017) | 1960-2000 | Non-OECD (192) | T, P, D | M | W | Natural disasters tend to deter emigration, but spur empigration to neighboring countries. Important interactions with wealth level. |
| Mahajan & Yang (2017) | 1980-2004 | World (159) | D | M | - | Hurricanes increase U.S. immigration, with the effect increasing in the size of prior migrant stocks. |
| Gröschl & Steinwachs (2017) | 1980-2010 | World (226) | T, P, D | M | W | No robust effect of environmental conditions on migration<br>Evidence that env. Migration stronger in middle income c. |
| Damette & Gittard (2017) | 1960-2000 | SSA (39) | T, P | M | A | Environmental measures as important migration drivers.<br>Remittance flows as important moderator |
| Aburn & Wesselbaum (2017) | 1980-2014 | World (198) | T, D | M | A, W | T, D $\xrightarrow{+}$ M stronger in agricultural and poorer c.<br>Different responses of migration to different types of disasters<br>Important dynamics over time |
| Cattaneo & Bosetti (2017) | 1960-2000 | World (226) | T, P, D | M | W | Short-term events have substantial effect on migration, especially in middle-income countries. Climate migrants not a driver of conflict |
| Cai et al. (2016) | 1980–2010 | World (163) | T, P | M | A | T $\xrightarrow{+}$ M, effect mainly driven by agricultural c.<br>Relationship is non-linear (extreme heat strongest effect)<br>Climate-induced migration specifically enlarges the flow in already established migration routes |
| Cattaneo & Peri (2016) | 1960-2000 | World (115) | T, P | U, M | A, W | T $\xrightarrow{+}$ U, M for middle-income c.<br>T $\xrightarrow{-}$ U, M for poor c. and agricultural c.<br>Positive impact of migration on GDP (only for middle-income) |
| Maurel & Tuccio (2016) | 1960-2000 | World (222) | T, P | U, M | W | T, P $\xrightarrow{+}$ U $\xrightarrow{+}$ M, effect particularly pronounced for developing c.<br>Anomalies boost urbanization and this spurs international migration |
| Peri et al. (2016) | 1970-2000 | World (210) | T, P | Internal (I) | W | T $\xrightarrow{-}$ I for poor c.<br>T $\xrightarrow{+}$ I for middle-income c.<br>Economic factors dominant, but climatic conditions also play a role |

Table 1 – Overview of country-level studies on environmental migration (continued)

| Study | Period | Sample (N) | Env | Migration | Heterogeneity | Main Findings |
|---|---|---|---|---|---|---|
| Henderson et al. (2016) | 1990-2009 | SSA (27) | P | U | - | Higher urbanization because of climatic shocks for cities with strong manufacturing sector. No effect for agriculturally dependent cities |
| Backhaus et al. (2015) | 1995-2006 | World (142) | T, P | M | State fragility | T, P (+)→ M, effect mainly driven by agricultural dependence<br>Importance of climate for emigration from European countries<br>State fragility does not seem to moderate the climate effects |
| Beine & Parsons (2015) | 1960-2000 | World (226) | T, P, D | U, M | W | D (+)→ U<br>No evidence for direct effects of other climate variables on M<br>Indirect effect through wages |
| Coniglio & Pesce (2015) | 1990–2001 | World (128) | T, P | M | A, W | P (+)→ M for poorer and agricultural c.<br>P (−)→ M for wealthier and non-agricultural c.<br>Evidence for both direct and indirect (income) effects |
| Drabo & Mbaye (2015) | 1975-2000 | Developing (67) | T, P, D | M | Region and education (~W) | D (+)→ M for highly educated<br>Little env. Migration in SSA, ECA, and SA. High levels in LAC<br>Effects mainly driven by hydrological disasters |
| Ghimire et al. (2015) | 1998-2009 | World (126) | P | Displacement | - | P (+)→ Displacement<br>M can fuel existing conflicts, esp. in developing c. (Hsiang et al. 2015) |
| Ruyssen & Rayp (2014) | 1980-2000 | SSA (42) | T, D | M | - | No robust evidence for climate effects<br>Env. conditions in destination c matter (negative pull effects) |
| Bettin & Nicolli (2012) | 1960-2000 | World (231) | T, P, D | M | W, A | T, R (+)→ M for low-income c.<br>T, R (−)→ M for agricultural c.<br>Disasters have strong effect on migration in Asia |
| Hanson & McIntosh (2012) | 1980-2005 | LAC (25) | D | M | Migration policy | D (+)→ M only to the US<br>Larger and richer cohorts more likely to migrate to US |
| Marchiori et al. (2012) | 1960-2000 | SSA(39) | T, P | U, M | A | T (−)→ U, T (+)→ M for non-agricultural c.<br>T (+)→ U, T (−)→ M for agricultural c.<br>Amenity vs economic geography channel |
| Ragazzi (2012) | 1960-2000 | World (182) | T, P, D | M | - | T, P (+)→ M |
| Brückner (2012) | 1960-2007 | Africa (41) | P | U | A | Decreases in the share of agricultural value because of climatic influenced lead to a significant increase in the urbanization rate |
| Gröschl (2012) | 1960-2010 | World (226) | D | M | - | Disasters are on average positively associated with migration out of affected areas. Results particularly driven by middle-income countries |

Table 1 – Overview of country-level studies on environmental migration (continued)

| Study | Period | Sample (N) | Env | Migration | Heterogeneity | Main Findings |
|---|---|---|---|---|---|---|
| Alexev et al. (2011) | 1986-2006 | World (178) | D | M | - | D ➨ M |
| Naudé (2010) | 1965-2005 | SSA (45) | D | M | - | Demographic and environmental pressures are found to have only a weak direct impact. Potential indirect channels of influence |
| Reuveny & Moore (2009) | 1988-1999 | World (X) | D | M | - | D ➨ M<br>Worsening prospects under continuing climate change |
| Naudé (2009) | 1965-2005 | SSA (45) | D | M | - | D ➨ M, results not robust<br>Env. has indirect impact through conflict and job opportunities |
| Afifi & Warner (2008) | 1960-2000 | World (226) | D | M | - | D ➨ M |
| Barrios et al. (2006) | 1960-1990 | Developing (78) | P | U | Region, historical | P ➨ U, mainly in SSA compared to other developing countries<br>Colonial past may be responsible for these patterns |

Note: The table gives a simplified overview of studies on environmental migration which use country level macro data in the estimation. The main findings reflect the interpretation of the results by the authors and the conclusions derived from it. Abbreviations: T = Temperature, P=Precipitation, D=Disaster (short-term events), U = Urbanization (most commonly used measure for internal migration), M=International migration, A=Heterogeneity along the agricultural vs. non-agricultural dimension, A=Heterogeneity along the wealth dimension, Env=environment(al), c=country, SSA=Sub-Saharan Africa, LAC=Latin America and the Caribbean, LMIC=Low and Middle Income countries

## 4.2 Estimating Average Climate Effects

In the first step of the quantitative analysis, we estimate the average effect of the standardized climate measures on migration (both internal and international). As we are still in the process of retrieving study line information and standardizing the parameters of interests (to be completed by end of February 2019), the evidence presented in the following is preliminary. It relies on a total number of approximately 1500 study lines (out of a total of more than 1800), retrieved from 25 (out of 32) studies, which analyze the climate migration link using country-level data.

Figure 5 shows the total distribution of standardized climate effects for all encoded study lines. Recall that the standardized effect sizes measure the standard deviation change in migration for one standard deviation change in the climate factor. At first, we neglect any differences in study design, climate measures, and context, but focus only on the overall relationship as reported by the studies. This first step is accompanied with a detailed discussion of some key descriptive statistics for the analyzed studies, such as. differences in climate measures, regionals studies, and longitudinal trends (not yet reported in the paper).

Clearly, as the histogram shows, the majority of effect sizes are rather small and scattered around the value of zero with a slight inclination towards the positive side. A first random effects meta-regression, which also accounts for the standard errors of study line coefficients, confirms climate effects across study lines are positive. This suggests that climatic shocks and hazards lead to greater internal and international migration, on average.

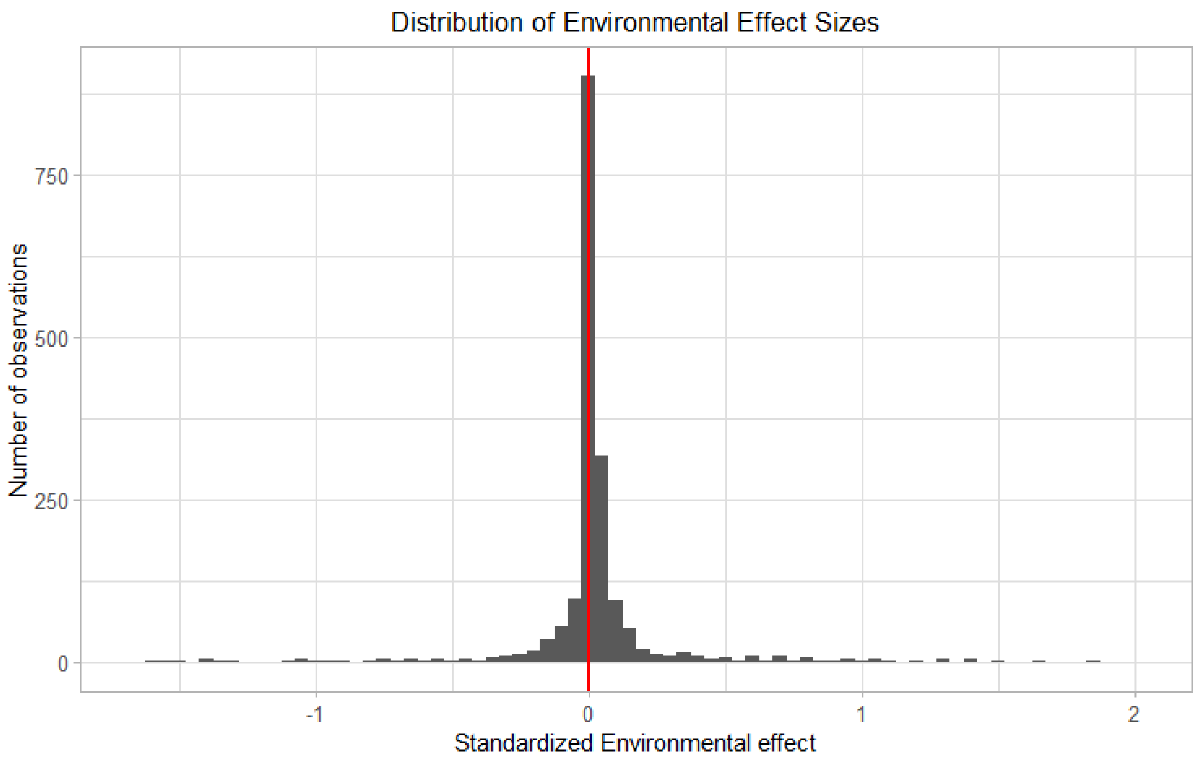


Figure 5 – Distribution of standardized climate effects across individual study lines

At the same time, however, Figure 5 also shows a significant heterogeneity in effect sizes with some study lines indicating a strong negative climate effect on migration, in support of the climate inhibitor argument. We further explore this heterogeneity by plotting the distribution of effect sizes across the different included studies. Figure 6 shows the distribution of effect sizes across and within studies. The average standardized effect is depicted with a blue dashed line. While most studies report significant positive climate effects, substantial differences in effect sizes exist between and within the single studies. In the next step of our analysis, we explore the drivers of these heterogeneities and test whether climate effects remain significant once we control for study line specific features, the context considered, and whether theoretically relevant factors were included in the original models.

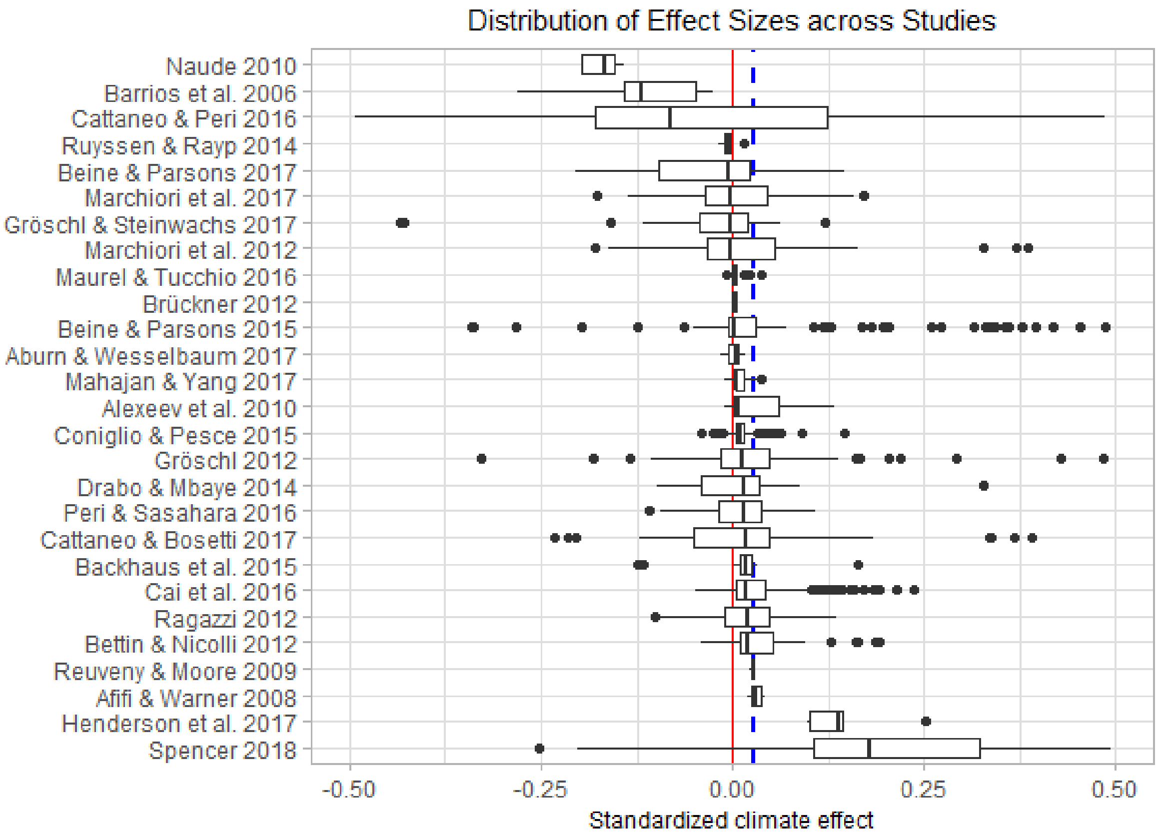


Figure 6 – Differences in standardized climate effects between studies

## 4.3 Exploring Heterogeneities across Study Lines

Table 2 shows linear fixed effect meta-regression models in which the standardized climate effects derived from the study lines are regressed on different explanatory variables related to the climate and migration variables considered in the study lines, publication aspects, theoretical mechanisms, and compositional effects. Aside of paper fixed effects, all models control for further study line specific characteristics, such as the sample size of the models, the number of countries considered, whether the obtained coefficient was derived from an interaction, and whether the study line models control for time and spatial fixed effects as well as the migration level in the countries. The coefficients are measured as standard deviation changes in the standardized coefficients.

Confirming previous findings in the literature, our results show that environmental migration is primarily internal. Studies, which consider international as opposed to internal migration, find an on average by 0.345 sd smaller standardized environmental effect (model 3). If we consider the type of environmental hazard considered in the study line models, we do not find any differences in effect sizes between temperature changes as reference category and precipitation changes or droughts. Rapid-onset events, such as floods, storms, or other disasters, on the other hand, are found to result in a by 0.144sd higher migration response ($p<0.01$). This does not imply that other environmental hazards are not relevant drivers of environmental migration, as can be inferred from the positive intercept, which roughly reflects the estimated baseline internal migration response to a one sd temperature change in high-income countries (all compositional shares = 0).

If we compare study line models by different types of publications, we find further interesting results. While the share of citations of the paper in Google Scholar is not significantly related with the effect sizes, the publication in a journal and the corresponding impact factor are. On average, coefficients reported in published papers are substantially higher compared to non-published findings, which could potentially indicate a publication bias in the literature. The discrepancy between published and unpublished works is smaller for findings which were published in a higher impact journal (max impact factor of all considered studies is 2.562)

Next we consider the role of theoretical mechanisms that might explain the reported environmental effects. In particular, we are interested in whether study-lines controlled for factors, which could potentially mediate the relationship between the environment and mobility outcomes. If a factor is a relevant mediator, we would expect the estimate coefficient to be lower as compared to a model, which does not control for the mediator and which hence capture the total environmental effect, including the indirect effect that runs the mediator. Indeed, we find suggestive evidence that some of the considered factors can be potential mechanisms in the environmental-migration relationship. Among all considered factors, environmental effects are most strongly reduced, if the study line model controls for the occurrence of conflict, which has been shown to be influenced by environmental changes and which is at the same time one of the main migration push factors (Hsiang et al 2013, Abel et al 2019). The standardized coefficients are also smaller if models control for income, which may be negatively affected by environmental shocks, but this relationship is only significant in model 2.

Finally, we analyze the effect of the sample composition on the size of the standardized coefficients. The first model considers only the compositional measures related to countries' wealth levels, the second model focusses on agricultural dependence and the prevalence of environmental migration in different world regions. The final model combines all compositional measures (maybe mention collinearity issue).

Table 2 – Fixed Effects Meta-Regression Models - Predicting standardized climate effects

| | Outcome variable: **Standardized Environmental Effect** | | |
|---|---|---|---|
| | (1) | (2) | (3) |
| **Climate & Migration** | | | |
| International migration | -0.311*** (0.060) | -0.344*** (0.060) | -0.345*** (0.060) |
| Rapid-onset | 0.144*** (0.051) | 0.155*** (0.050) | 0.141*** (0.050) |
| Precipitation change | -0.002 (0.028) | -0.003 (0.028) | -0.002 (0.028) |
| Draught | 0.028 (0.137) | 0.035 (0.135) | 0.024 (0.134) |
| Lag of environmental shock | -0.010 (0.013) | -0.009 (0.013) | -0.009 (0.013) |
| **Publication aspects** | | | |
| # citations in Google Scholar | 0.006 (0.009) | 0.006 (0.009) | 0.006 (0.009) |
| Published in Journal (0/1) | 0.559 (0.542) | 1.898*** (0.562) | 1.541*** (0.568) |
| Impact factor x Published | -0.441* (0.229) | -1.401*** (0.257) | -1.095*** (0.279) |
| **Theoretical mechanisms** | | | |
| Income controlled for | -0.100 (0.063) | -0.106* (0.062) | -0.089 (0.062) |
| Conflict controlled for | -0.412*** (0.126) | -0.349*** (0.125) | -0.374*** (0.124) |
| Population controlled for | 0.042 (0.101) | 0.031 (0.100) | 0.035 (0.099) |
| Urbanization controlled for | 0.391*** (0.123) | 0.418*** (0.121) | 0.406*** (0.120) |
| **Composition effects** | | | |
| % low-income countries in sample | -0.330*** (0.119) | | -1.722*** (0.341) |
| % lower-middle-income countries | 0.725*** (0.116) | | 0.363* (0.211) |
| % upper-middle-income countries | 0.133 (0.277) | | -0.618 (0.383) |
| % agriculturally dependent countries | | 0.582*** (0.204) | 1.676*** (0.289) |
| % countries in Asia | | 0.288 (0.233) | 0.603* (0.310) |
| % countries in SSA | | -0.521** (0.240) | 0.031 (0.320) |
| % countries in MENA | | 1.071*** (0.322) | 0.692** (0.348) |
| % countries in LAC | | 1.802*** (0.223) | 1.399*** (0.393) |
| Intercept | 0.768*** (0.277) | 0.310 (0.284) | 0.559* (0.295) |
| Paper fixed effects | yes | yes | yes |
| Study line controls | yes | yes | yes |
| Observations | 1,609 | 1,609 | 1,609 |
| # studies | 28 | 28 | 28 |
| Adjusted $R^2$ | 0.234 | 0.251 | 0.264 |

Note: Coefficients with standard errors in parentheses. Further controls included, but not displayed: sample size of study line, number of countries considered, use of time and spatial fixed effects, whether study line controls for migration level, and factor whether coefficient was derived from interaction effect. P value: * <0.1, ** <0.05, *** <0.01.

Interestingly, we find lower levels of environmental migration for study lines which use samples with a higher share of low-income countries. At the same time, we substantially higher coefficients in samples with a high share of lower-middle-income countries, for which the phenomenon of environmental migration seems to be most prevalent. This finding is in line with the notion that it requires a certain level of resources to migrate, which imposes constraints in low-income settings. At the same time, the finding could also reflect a climate inhibitor mechanism (Fussell et al. 2014; Nawrotzki & Bakhtsiyarava 2016), which suggests that environmental shocks may lead to a reduction in migration, if resources needed for the mobility are destroyed due to the shock. The migration opportunities of richer vs. poorer countries are different and this may worsen because of environmental shocks and hazards.

Although being strongly correlated with the share of low-income countries, we find that a higher share of agriculturally dependent countries in a study-line sample increases environmental effects on migration. This effect, although different in size, persists in the final model, once all compositional measures are controlled for. At the same time, we observe major regional differences in the strength of environmental migration. Compared to the high-income reference, we observe increasing environmental migration with a larger share of Asian, and in particular Middle Eastern and North African and Latin American and Caribbean countries in the study line samples. In contrast, we observe reduced levels of migration in Sub Saharan Africa, which may reflect negative income effects and greater migration limitations.

### 4.4 Predictions

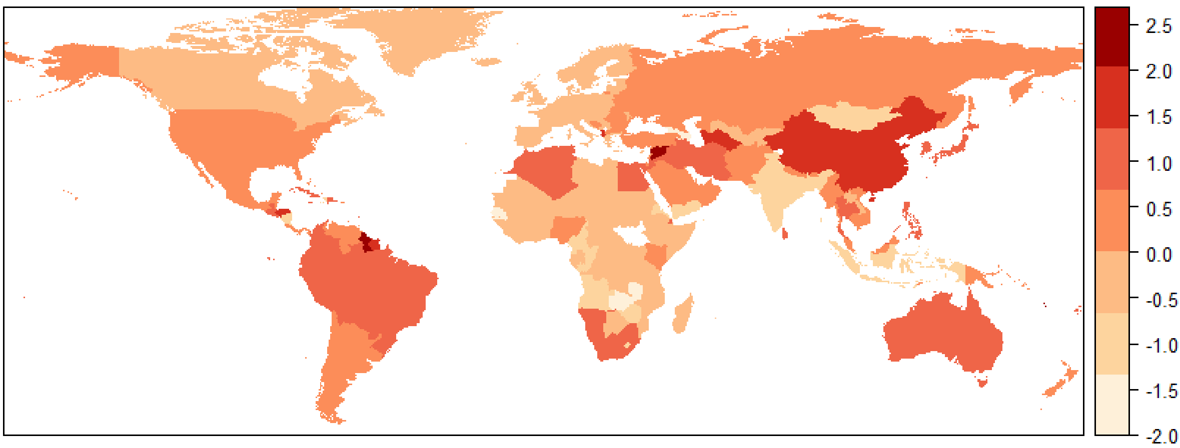


Figure 7 – Predicted migration coefficients based on model 3

## 5 Discussion and Further Steps

Someone needs to go through and che

The research project is ongoing. We plan to encode and standardized the coefficients from the last missing studies and finalize the analysis by end of February 2019. As next steps, we plan to take further explore the role of contextual variables and to take a closer look at some of the interactions between different study line characteristics. These may play an important role in influencing the migration response to environmental hazards and shocks. Although preliminary, our first results suggest that environmental migration is a complex phenomenon, which strongly depends on contextual, non-environmental factors. Our analysis can deliver important insights in the environment-migration nexus and inform both the scientific and political community.

## References


Aburn, A. & Wesselbaum, D., 2017. Gone with the Wind: International Migration. *University of Otago Economics Discussion Papers No. 1708*, 2293(1708).

Afifi, T., 2011. Economic or Environmental Migration? The Push Factors in Niger. *International Migration*, 49(SUPPL.1).

Afifi, T., Liwenga, E. & Kwezi, L., 2014. Rainfall-induced crop failure, food insecurity and out-migration in Same-Kilimanjaro, Tanzania. *Climate and Development*, 6(1), pp.53–60.

Afifi, T. & Warner, K., 2008. The Impact of Environmental Degradation on Migration Flows across Countries. , Working Pa, pp.1–25.

Alexeev, A., Good, D.H. & Reuveny, R., 2011. Weather-Related Disasters and International Migration. *Draft, Indiana University*.

Alscher, S., 2011. Environmental Degradation and Migration on Hispaniola Island. *International Migration*, 49(SUPPL.1).

Angrist, J.D. & Pischke, J.-S., 2009. Mostly Harmless Econometrics, Princeton: Princeton University Press.

Backhaus, A., Martinez-Zarzoso, I. & Muris, C., 2015. Do climate variations explain bilateral migration? A gravity model analysis. *IZA Journal of Migration*, 4(1).

Barrios, S., Bertinelli, L. & Strobl, E., 2006. Climatic change and rural-urban migration: The case of sub-Saharan Africa. *Journal of Urban Economics*, 60(3), pp.357–371.

Beine, M., Bertoli, S. & Fernández-Huertas Moraga, J., 2016. A Practitioners' Guide to Gravity Models of International Migration. *World Economy*, 39(4), pp.496–512.

Beine, M. & Jeusette, L., 2018. A Meta-Analysis of the Literature on Climate Change and Migration,

Beine, M. & Parsons, C., 2015. Climatic Factors as Determinants of International Migration. *The Scandinavian Journal of Economics*, 117(2), pp.723–767.

Bettin, G. & Nicolli, F., 2012. Does climate change foster emigration from less developed countries ? Evidence from bilateral data. *Universita degli Studi Di Ferrara Working Paper*, 10.

Black, R., Arnell, N.W., Adger, W.N., Thomas, D. & Geddes, A., 2013. Migration, immobility and displacement outcomes following extreme events. *Environmental Science and Policy*, 27, pp.S32–S43.

Black, R., Stephen, R., Bennett, G., Thomas, S.M. & Beddington, J.R., 2011. Migration as adaptation. *Nature*, 478, pp.447–449.

Bohra-Mishra, P., Oppenheimer, M., Cai, R., Feng, S. & Licker, R., 2017. Climate variability and migration in the Philippines. *Population and Environment*, 38(3), pp.286–308.

Borenstein, M., Hedges, L. V., Higgins, J.P.T. & Rothstein, H.R., 2010. A basic introduction to fixed-effect and random-effects models for meta-analysis. *Research Synthesis Methods*, 1(2), pp.97–111.

Borenstein, M., Hedges, L. V., Higgins, J.P.T. & Rothstein, H.R., 2009. Introduction to Meta-Analysis, Chichester, UK: John Wiley & Sons.

Breen, R., Karlson, K.B. & Holm, A., 2013. Total, Direct, and Indirect Effects in Logit and Probit Models. *Sociological Methods and Research*, 42(2), pp.164–191.

Burke, M., Hsiang, S.M. & Miguel, E., 2015. Climate and Conflict. *Annual Review of Economics*, 7, pp.577–617.

Cai, R., Feng, S., Oppenheimer, M. & Pytlikova, M., 2016. Climate variability and international migration: The importance of the agricultural linkage. *Journal of Environmental Economics and Management*, 79, pp.135–151.

Cattaneo, C. & Peri, G., 2016. The migration response to increasing temperatures. *Journal of Development Economics*, 122, pp.127–146.

Challinor, A.J., Watson, J., Lobell, D.B., Howden, S.M., Smith, D.R. & Chhetri, N., 2014. A meta-analysis of crop yield under climate change and adaptation. *Nature Climate Change*, 27(March), pp.1–5.

Coniglio, N.D. & Pesce, G., 2015. Climate variability and international migration: An empirical analysis. *Environment and Development Economics*, 20(4), pp.434–468.

Crespo Cuaresma, J., Fidrmuc, J. & Hake, M., 2014. Demand and supply drivers of foreign currency loans in CEECs: A meta-analysis. *Economic Systems*, 38(1), pp.26–42.

Dethier, J.-J. & Effenberger, A., 2012. Agriculture and development: A brief review of the literature. *Economic Systems*, 36(2), pp.175–205.

Drabo, A. & Mbaye, L.M., 2015. Natural disasters, migration and education: an empirical analysis in developing countries. *Environment and Development Economics*, 20(06), pp.767–796.

Fussell, E., Hunter, L.M. & Gray, C.L., 2014. Measuring the environmental dimensions of human migration: The demographer's toolkit. *Global Environmental Change: Human and Policy Dimensions*, 28, pp.182–191.

Ghimire, R., Ferreira, S. & Dorfman, J.H., 2015. Flood-induced displacement and civil conflict. *World Development*, 66, pp.614–628.

Gray, C. & Mueller, V., 2012. Drought and Population Mobility in Rural Ethiopia. *World Development*, 40(1), pp.134–145.

Gray, C. & Wise, E., 2016. Country-specific effects of climate variability on human migration. *Climatic Change*, 135(3–4), pp.555–568.

Gray, C.L., 2009. Environment, Land, and Rural Out-migration in the Southern Ecuadorian Andes. *World Development*, 37(2), pp.457–468.

Grecequet, M., DeWaard, J., Hellmann, J.J. & Abel, G.J., 2017. Climate Vulnerability and Human Migration in Global Perspective. *Sustainability*, 9(5), p.720.

Gröschl, J. & Steinwachs, T., 2016. Do Natural Hazards Cause International Migration? *CESifo Working Paper No 6145*.

Hanson, G.H. & McIntosh, C., 2012. Birth Rates and Border Crossings: Latin American Migration to the US, Canada, Spain and the UK. *Economic Journal*, 122(561), pp.707–726.

Henry, S., Schoumaker, B., Beauchemin, C., Population, S. & May, N., 2004. The Impact of Rainfall on the First Out-Migration : A Multi-level Event-History Analysis in Burkina Faso All use subject to JSTOR Terms and Conditions The Impact of Rainfall on the First Out-Migration : A Multi-level Event-History Analysis in Burkina Faso. *Population and Environment*, 25(5), pp.423–460.

Hoffmann, R. & Muttarak, R., 2017. Learn from the Past, Prepare for the Future: Impacts of Education and Experience on Disaster Preparedness in the Philippines and Thailand. *World Development*, 96.

Hsiang, S.M., Burke, M. & Miguel, E., 2013. Quantifying the Influence of Climate on Human Conflict. *Science*, 341(6151), p.1235367.

Hunter, L.M., 2005. Migration and environmental hazards. *Population and Environment*, 26(4), pp.273–302.

Hunter, L.M., Luna, J.K. & Norton, R.M., 2015a. Environmental dimensions of migration. *Annual Review of Sociology*, 41(1), p.null.

Hunter, L.M., Luna, J.K. & Norton, R.M., 2015b. Environmental Dimensions of Migration. *Annual Review of Sociology*, 41(1), pp.377–397.

Hunter, L.M. & Nawrotzki, R., 2016. Migration and the Environment. *International Handbook of Migration and Population Distribution 6*, (December), pp.465–484.

Hunter, L.M., Nawrotzki, R., Leyk, S., Maclaurin, G.J., Twine, W., Collinson, M. & Erasmus, B., 2014. Rural Outmigration, Natural Capital, and Livelihoods in South Africa. *Population, Space and Place*, 20(5), pp.402–420.

IOM, 2012. People on the Move in a Changing Climate: The Regional Impact of Environmental Change on Migration, Geneva: International Organization for Migration.

Lipsey, M.W. & Wilson, D.B., 2001. Practical meta-analysis. *Applied Social Research Methods Series*, 49, p.264.

Marchiori, L., Maystadt, J.-F. & Schumacher, I., 2017. Is environmentally induced income variability a driver of human migration? *Migration and Development*, 6(1), pp.33–59.

Marchiori, L., Maystadt, J.F. & Schumacher, I., 2017. Is environmentally-induced income variability a driver of migration? *Migration and Development*, 6(1), pp.33–59.

Marchiori, L., Maystadt, J.F. & Schumacher, I., 2012. The impact of weather anomalies on migration in sub-Saharan Africa. *Journal of Environmental Economics and Management*, 63(3), pp.355–374.

Martinez-Zarzoso, I., Murris & Backhaus, A., 2012. International Migration and Climate Change. *University Jaume 1 Working Paper*, pp.1–13.

Maurel, M. & Tuccio, M., 2016. Climate Instability, Urbanisation and International Migration. *Journal of Development Studies*, 52(5), pp.735–752.

McLeman, R. & Smit, B., 2006. Migration as an adaptation to climate change. *Climatic Change*, 76(1–2), pp.31–53.

Mendelsohn, R. & Dinar, A., 1999. Climate Change, Agriculture, and Developing Countries: Does Adaptation Matter? *The World Bank Research Observer*, 14(2), pp.277–293.

Mueller, V., Gray, C. & Kosec, K., 2014. Heat stress increases long-term human migration in rural Pakistan. *Nature Climate Change*, 4(3), pp.182–185.

Naudé, W., 2008. Conflict, Disasters and No Jobs: Reasons for international migration from sub-Saharan Africa. *United Nations University WIDER Research Paper*, (85).

Nawrotzki, R.J. & Bakhtsiyarava, M., 2016. International Climate Migration: Evidence for the Climate Inhibitor Mechanism and the Agricultural Pathway. *Population, Space and Place*, 23(4).

Nawrotzki, R.J., Riosmena, F. & Hunter, L.M., 2013. Do Rainfall Deficits Predict U.S.-Bound Migration from Rural Mexico? Evidence from the Mexican Census. *Population Research and Policy Review*, 32(1), pp.129–158.

Obokata, R., Veronis, L. & McLeman, R., 2014. Empirical research on international environmental migration: A systematic review. *Population and Environment*, 36(1), pp.111–135.

Peri, G., Davis, U.C. & Davis, U.C., 2016. Global Warming and Internal Migrations : Evidence from a Gridded Dataset from the. , pp.1970–2000.

Piguet, E., 2010. Linking climate change, environmental degradation, and migration: A methodological overview. *Wiley Interdisciplinary Reviews: Climate Change*, 1(4), pp.517–524.

Ragazzi, P., 2012. Climate Change and Migration: A Gravity Model Approach. *Quaderni DEM, volume 1*.

Reuveny, R. & Moore, W.H., 2009. Does environmental degradation influence migration? Emigration to developed countries in the late 1980s and 1990s. *Social Science Quarterly*, 90(3), pp.461–479.

Rothstein, H.R., Sutton, A.J. & Borenstein, M., 2006. Publication Bias in Meta-Analysis: Prevention, Assessment and Adjustments,

Rowlands, D., 2004. The Effects of Poverty, Environmental Degradation, and Gender Conditions on South—to—North Migration. *Canadian Journal of Development Studies / Revue canadienne d'études du développement*, 25(4), pp.555–572.

Ruyssen, I. & Rayp, G., 2014. Determinants of Intraregional Migration in Sub-Saharan Africa 1980-2000. *Journal of Development Studies*, 50(3), pp.426–443.

Schlenker, W. & Lobell, D.B., 2010. Robust negative impacts of climate change on African agriculture. *Environmental Research Letters*, 5(1).

Sterne, J., 2009. Meta-Analysis: An Updated Collection from the Stata Journal, College Station, USA: Stata Press.

Warner, K., 2011. Environmental change and migration: Methodological considerations from ground-breaking global survey. *Population and Environment*, 33(1), pp.3–27.

Wrathall, D.J., 2012. Migration Amidst Social-Ecological Regime Shift: The Search for Stability in Garífuna Villages of Northern Honduras. *Human Ecology*, 40(4), pp.583–596.

# Appendix

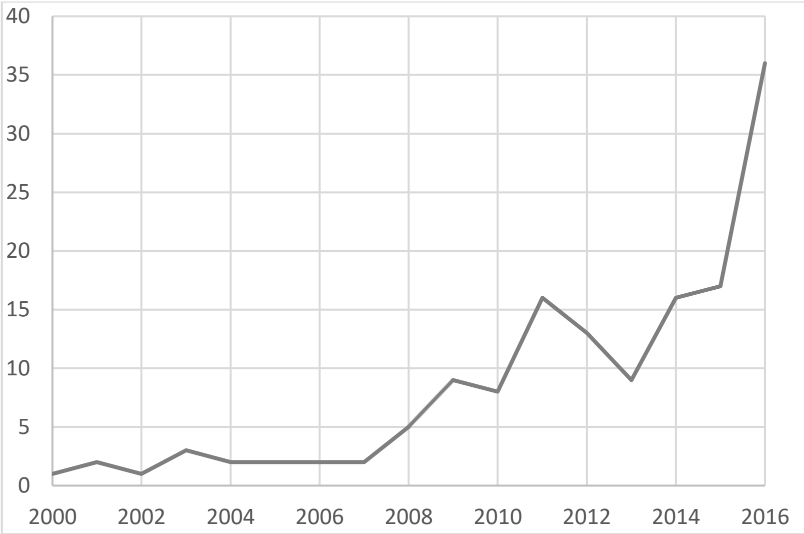


Figure A1 – Number of quantitative empirical studies on environmental migration since 2000

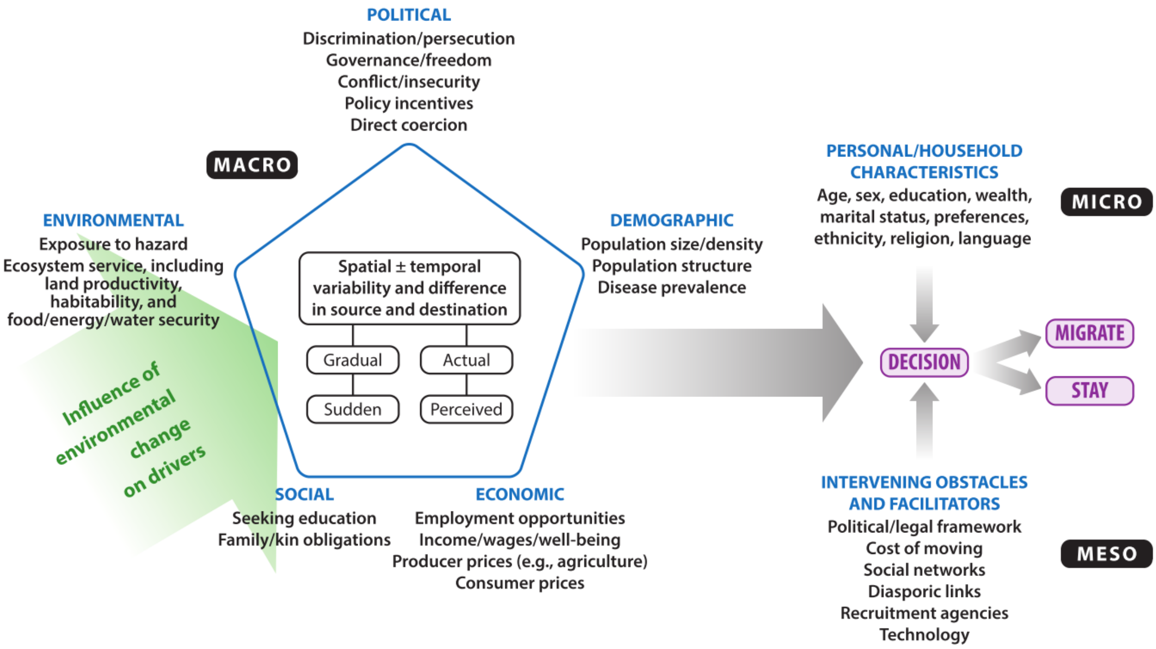


Figure A2 - Drivers of migration and the role of contextual factors (Source: Black et al. 2012)

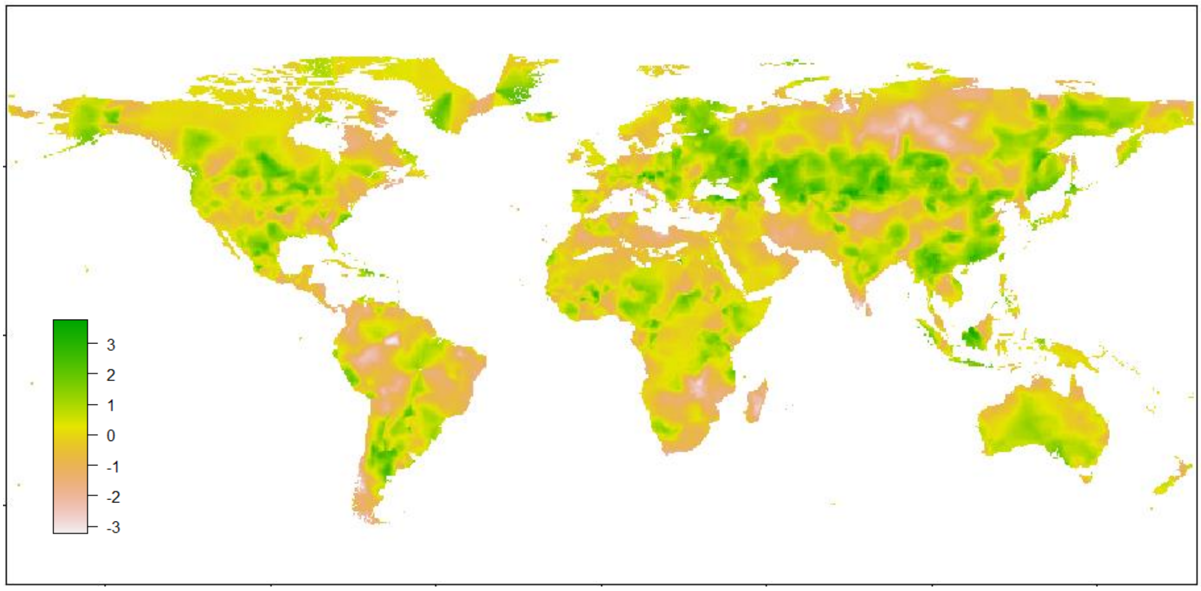


Figure A3 - Precipitation 2016: Standard deviations from long-term average 1950-2