Environmental Migration Flows in Vietnam

Vally Koubi[1,2], Sebastian Stoll[3], Tobias Siegfried[1,4], and Lucas Beck[1,4]

Abstract

The argument that environmental change is an important driving force of migration has experienced a strong revival in the climate change context. Yet, knowledge in this issue remains limited and fragmented. In his paper we contribute to the literature in this field by focusing on the micro-level. We examine whether and how individual perceptions of different types of environmental events (i.e., *sudden* and *short-term* environmental events such as storms vs *slow-onset* and *long-term* environmental events such as droughts) affect migration decisions. Using a computational model, we simulate the climate-induced migration for alternative future climate scenarios. Newly collected micro-level data (1,200 migrants and non-migrants) from Vietnam is used to calibrate the model. Results show that migrants perceive *sudden* and *short-term* environmental events as more extreme compared to non-migrants; in the future the average proportion of migration among individuals increases due to increases in heavy precipitation events.

Keywords: climate change, droughts, floods, storms, migration, computational model, Vietnam.

[1] CIS, ETH Zurich

[2] Dept. of Economics University of Bern

[3] Water Resources and Drinking Water, Eawag

[4] Hydrosolutions GmbH

Authors' Note: This research is part of the project "Environmental Change and Migration" funded by the Swiss Network for International Studies (SNIS).

Introduction

Climate change is recognized as a global issue. Climate change manifest itself with temperature increases, changes in precipitation, sea level rise, and the intensification of natural hazards, such as storms (cyclones), floods, and droughts (IPCC 2013). The Intergovernmental Panel on Climate Change (IPCC 2013), academics and policy-makers argue that climate changes are likely to cause mass population dislocations (migration). For instance, studies estimate that 187 to 600 million people living in low elevation coastal areas, such as some islands (e.g. Tuvalu and Maldives) and in major river deltas and estuaries in East and South Asia, would be affected by sea-level rise alone (Nicholls et al. 2011; MacGranahan et al. 2007; Anthoff et al. 2006). Some studies even predict that these environmental events and processes could force 200 million (Biermann and Boas 2010; Myers 2002) to 1 billion (Christian Aid 2007) people to move permanently or temporarily within their own countries or internationally.

These estimates, however, have been heavily criticized that they tend to overestimate the number of 'environmental migrants'[1] because they are usually based on the number of people exposed to increasing risks, and not on the number of people actually expected to migrate; and they do not account for adaptation strategies and different levels of vulnerability to change (Gemenne 2011; Foresight Project 2011).[2] Consequently, such estimates fail to adequately acknowledge the effects of individuals' characteristics on migration behavior as well as individuals' perceptions of the environmental problem and hence they have not successfully isolated the environmental influences from the multitude of other factors that influence migration.

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[1] We use the term "environmental migration" as relating to persons who are displaced primarily for environmental reasons (See Dun and Gemenne (2008) for a discussion on the definition of environmental migration).

[2] Piguet (2010) offers an excellent review of the methods to assess the weight of the environment in migration processes.

Moreover, the existing empirical literature on the environment-migration nexus is rather fragmentary. It relies mainly on case studies (e.g., Gray and Mueller 2012; Doevenspeck 2011; Van der Geest 2011; Massey et al. 2010; Mortreux and Barnett 2009; Gray 2008). These studies offer interesting insights into the complex relationship between environmental stresses and migration, suggesting that migration dynamics are location and context specific and thus findings are hard to generalize (Hunter 2005). In addition, the existing literature does not tell us much about how different environmental events affect individuals' decisions to migrate or stay.

In this context, computational modeling offers a robust method to model individuals' decisions regarding migration by projecting the impact of physical change upon human systems. Although several authors have acknowledged the potential for computational models, for instance Agent Based Models (ABM), to significantly contribute to and improve our understanding of the population movements linked to climate change (Piguet 2012; 2010; McLeman 2012), still such models have been applied to simulate migration responses to climate change in only a few studies. Kniveton et al (2012) and Kniveton et al (2011) used an ABM combined with the theory of planned behavior to study the link between climatic change in the form of rainfall, socioeconomic and political factors and migration, under different scenarios in Burkina Faso. They found that dry climate scenarios produce increased migration fluxes compared to the wet scenarios and concluded that climate change is likely to play a significant role in shaping migration patterns in the coming decades. Similarly, Smith (2014) developed and tested an ABM of livelihood stress and migration using survey data collected in three villages of Same district, Kilimanjaro region, Tanzania in 2012. He used a range of artificial rainfall scenarios and found that compared to a base scenario total migration flows were greater under a wet scenario and lesser under a dry one. Finally, Hassani-Mahmooei and Parris (2012) implemented an ABM with district level data to analyze the effects of climate change on internal migration in Bangladesh. They reported that climate change would likely affect migration by increasing movements towards the east and north-east districts, which are less affected by droughts and floods, and estimated that between 3and 10 million people may migrate, depending on the severity of the environmental events.

In this paper we develop a computational model to simulate the effects of climate change on migration in Vietnam for the period 2010-2100. The main argument is that different types of environmental events – notably short- vs. long-term environmental problems- can create different incentives for people to migrate or stay. Our computational model combines individual (i.e., age, gender, education, employment), and household (i.e., household status and social networks) characteristics as well as projected climate changes in Vietnam. We find that while migrants and non-migrants perceive long-term environmental events, i.e., droughts, in a similar fashion, migrants tend to perceive short/sudden environmental events, i.e., storms as more extreme compared to non-migrants. Moreover, simulation results reveal that in the future environmental migration flows will increase due to increases in heavy precipitation events.

The next section briefly elaborates on the study area, followed by the presentation of our theoretical argument. Afterwards, we discuss our modeling strategy, before presenting the empirical results. The last section concludes with a discussion of our findings and the implications for future research and policymakers.

Study area: Vietnam

It has been alleged that the negative effects of climatic changes are likely to be felt more strongly in the developing countries compared to developed ones, as a large share of the population lives in exposed areas, depend directly on natural resources and the environment for their livelihood and have limited institutional capacities to take proactive measures.

A World Bank study (Dasgupta et al. 2007) has identified Vietnam among the countries which will be most heavily affected by climate change mainly due to its long coastlines (3,200 km) and the large deltas - which make it particularly susceptible to more intense and frequent natural disasters, rising sea levels, coastal erosion, and salt water intrusion- the high population density and the concentration of economic activity in coastal areas, and a heavy reliance on agriculture, fishery and forestry. For instance, of the 84 coastal developing countries investigated in the World Bank study in terms of sea level rise, Vietnam ranks first in terms of impact on population, GDP, urban extent, and wetland areas, and ranks second in terms of impact on land area (behind the Bahamas) and agriculture (behind Egypt). In particular, it is estimated that a 100cm rise in sea level by 2100 would affect approximately 40.000km2 (12.1 percent of Vietnam's land area) and 17.1 million people (23.1 percent of the population).[3]

In addition, the overall temperature in Vietnam in 2100, compared with the period of 1980-1999 is likely to increase by between 1.1-1.9^{0}C and 2.1- 3.6^{0}C; annual rainfall is likely to increase by between 1.6% - 14.6%. The potential impacts of climate change are likely to be most serious in the agricultural and the water resources sectors, and that flood inundation and droughts are likely to occur more frequently due to an increase in rainfall intensity and decline in number of rainy days. The Red River Delta and Quang Ninh province, the North Central Coast, South Central Coast and the Mekong River Delta were identified as the most vulnerable areas.

The country, however, is already experiencing changes in fundamental climatic elements as well as extreme weather phenomena such as storms, heavy rains, and droughts. Temperature is rising by 0.5-0.7^{0}C per 50 years, from the South to the North, and the frequency of cold fronts has decreased by 2.45 events per 50 years. Its coastal areas bear the brunt of tropical storms arising from the East Sea, with an average of almost 7 storms yearly.

[3] (IPCC http://www.ipcc.ch/ipccreports/tar/wg2/index.php?idp=446).

It has been observed that tropical cyclone frequency has increased by 2.15 events per 50 years, and the sea level has risen around 20cm per 50 years. In 2004, saltwater intruded into 30-50km in the Red river and 60-70km in the Mekong river, resulting in more than 1.7 million ha of land been affected by salination (Thanh et al. 2004). In 2013, Vietnam faced an unusually high number of natural disasters, including 15 intense typhoons causing 277 deaths/missing and 855 injuries and economic losses estimated at 28,000 billion VND, approximately double the rate recorded for 2012 (EM-DAT/ OFDA/CRED).

Theory

In this section, we present a simple theoretical model that is able to describe the underlying link from climate change to migration, and helps in motivating the modeling choices in the subsequent empirical analysis.

While most of the existing scientific literature on ‘environmental migration’ regards the environment-migration nexus as self-evident, still the environment-migration relationship may well be conditional on various individual, socio-economic, and political factors (Black et al. 2011). A recent body of literature has thus considered various economic, social, demographic, environmental, and other factors that may influence migration. However, as of now, there is no single, coherent theory of migration, but rather a fragmented set of theories, often segmented by disciplinary academic boundaries. However, once we consider migration as resulting from a combination of driving forces, environmental stressors can be integrated into existing explanations, such as those just mentioned (e.g. Black et al. 2011; Adger et al. 2007; Castles 2002; Lonergan 1998; Suhrke 1994). A very useful option for doing so is to draw on the ‘stress-threshold’ model (Wolpert 1966).

From the perspective of this model, environmental events, for instance floods, droughts, or desertification, can act as ‘stressors’ that bring about ‘strains’ and motivate individuals to consider migration as a response. However, the presence of an environmental stressor will, in most cases, not automatically induce migration (the main exception are major environmental hazards that leave local residents with no choice but to leave) (e.g. Adger et al. 2007). The reason is that migration is costly in both financial and sociological/psychological terms since individuals tend to develop strong personal bonds over their lives with their home location and its people (Devine-Wright 2013; Lewicka 2011). Consequently, an individual will consider migration only when environmental change has a major impact on her personal wellbeing and her efforts to adapt to and/or mitigate this impact are failing (Speare 1974).[4] To what extent this is the case depends on the form and magnitude of the environmental stressor.

The most interesting variation in this respect, in our view, is the difference between *sudden vs. slow-onset* and *short-term vs. long-term* environmental events.[5] Sudden and rapid (short-term) environmental events, such as floods or storms, can have severe impacts – at least in the short run – on the wellbeing of individuals. Affected individuals may migrate in the aftermath of such natural disasters (Naik 2009; Raleigh et al. 2008). On the other hand, slow-onset and long-term environmental problems, such as droughts, desertification, or sea- level rise, are likely to have smaller immediate impacts on the wellbeing of individuals. People can adjust their productive strategies over time when facing such environmental stressors, for example, via investment in irrigation systems, use of drought resistant plant and animal varieties, or diversification of income sources (Adger et al. 2001; Roncoli et al. 2001). Moreover, diversification of income sources might be accomplished by having a single-family member migrate (Adger et al. 2002; Massey et al. 1993).

Hunter (2005) among others has noted that, in addition to "objective" environmental stressors, perceptions of risk act as a 'mediating factor' between environmental stress and

[4] Lilleør and Van den Broeck (2011) provide a critical review of the existing theoretical and empirical research on how climate change and climate variability in Less Developed Countries (LDCs) could affect migration via their effect on personal income.
[5] Renaud et al. (2011) propose a similar decision framework for environmentally induced migration, arguing that the type of the environmental problem– rapid onset vs slow onset- affects whether migration is forced or voluntary.

migration. One reason is that environmental problems are likely to have asymmetric impacts across a given population. In addition, individual perspectives on any given environmental problem are almost by definition relative. They are, for instance, influenced by the ability of an individual to cope with and adapt to environmental problems. This ability may be a function of skills, financial assets, age, gender, health, and education (Piguet et al 2011). The empirical implication of this theoretical argument is that *perceptions of short-term environmental events are likely to motivate individuals to migrate because they affect their level of satisfaction with the current location.* However, given that individuals are tied to a particular location by lifestyle, bonds to other people, and cultural and social traditions, we expect that *perceptions of long-term environmental events are less likely to increase the probability of migration because affected individuals are more likely to have adapted to (increasingly) negative environmental conditions.*

Modeling future environmental migration flows

In order to test our theoretical propositions we use a computational model, which is calibrated with newly collected micro-level data from Vietnam. Individual level surveys were conducted in three 3 regions (Red River and Menkong Deltas and South Central Coast) of Vietnam which experience environmental problems and are considered to be vulnerable to climatic changes (the EM-DAT/OFDA/CRED). In particular the surveys were carried out in the provinces of *Ben Tre* (water salination and floods) and *An Giang* (floods) in the Menkong River Delta, *Ninh Thuan* (droughts) in South Central Coast, and *Nam Dinh* (typhoons and floods) as well as in the two major cities (*Hanoi* and *Ho Chi Min City*) in September and October 2013, producing 1,200 completed questionnaires in total of which 600 came from migrants.[6]

[6] We focus only on internal migration because a) there is a strong agreement in the existing literature that most environmental migration is internal (Adamo and Izazola 2010); and b) certain factors, which

The survey data provide comprehensive information on the attributes (age, sex, marital status, education, economic activities of the individual and his/her household), and actions (migration experience) of the respondents as well as their experience with environmental events during the last 5 years. It is worth noting that although the surveys provide a wealth of information that is useful for the parameterization of the variables in the model at the start of a simulation, it fails to provide an adequate basis from which to quantify the degree of change in these variables given some form of external change over time. Because of these data limitations, our model should be seen as heuristic case study-based approach that uses survey data to explore the role of climate in shaping migration decisions.

The migration decision of individuals is estimated as a function of environmental factors as well as individual characteristics using a logistic regression model.[7] Once the model is calibrated with the data from the questionnaires, different potential future climatic scenarios are directly applied and their effects on the migration dynamics are simulated.

Migration decision of an individual is described by the following logistic regression model:

$$\ln\left(\frac{\mathrm{P}(\mathrm{M}_{\mathrm{iy}})}{1-\mathrm{P}(\mathrm{M}_{\mathrm{iy}})}\right) = \beta_0 + \beta_1 Age_i + \beta_2 Edu_i + \beta_3 HHmig_i + \beta_4 Rain_{iy} + \beta_5 Dro_{iy} \qquad (1)$$

where M_{iy} is the migration intention of an individual i in a year y, Age_i the age of an individual and Edu_i the level of education. $HHmig_i$ describes if an individual has a family member which already migrated.[8] The last two predictors specify if the individual has experienced a year with an extreme heavy rain/flooding ($Rain_{iy}$) or a drought (Dro_{iy}) event,

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could influence people's decision to migrate such as a country's political system, social and or cultural factors, stay constant and therefore cannot influence the decision to migrate.

[7] Cai and Oppenheimer (2013) employ a similar approach..

[8] Our decision to include only a very limited number of individual characteristics is based on the findings of Clarke (2005, 2009), who shows that the inclusion of many control variables can actually increase the bias instead of decreasing it.

according to his/her perception. While Age and Edu are categorical variables the remaining predictors are binary variables. The regression coefficients β are calibrated with the data from the questionnaires.

Environmental change and perception of extreme events

To model the impact of future climatic change on the migration intention, it is necessary to know how extreme environmental events are perceived and how the frequencies of such events are expected to change in the future.

For both types of environmental events, i.e., sudden/short and slow-onset/long-term, the differentiation between extreme and non-extreme years is based on climatic data and the individual perception of the questionnaire participants. Each questionnaire participant answered the question if he/she experienced an extreme precipitation/drought event and when this event occurred. So, for each individual the number of days with heavy precipitation/without rain in a year can be extracted from the data described below. For individuals who did not experience any extreme event, the highest value during the last 5 years since before the year they moved (migrants) or during the last 5 years before 2013 (non-migrants) is used.

As the current and former locations of the questionnaire participants are known, we can compare their evaluation of the environmental event with measured objective environmental values and hence identify individual environmental thresholds for each survey participant. While years with larger values than the individual threshold indicate that the individual will perceive this year as an extreme one, the ones showing smaller values will be perceived as not extreme.

Climatic data

As basis to identify years with heavy precipitation events, a percentile-based threshold index is applied, reporting the number of days on which the daily precipitation exceeds the 99^{th} percentile (r99p) of the reference period 1961-1990. For droughts, the number of days without rain (r1mm) in a year is chosen. To calculate the individual thresholds and to get information about the projected future frequencies, we use the dataset from Sillman et al. (2013a, 2013b). Based on state-of-the-art global climate models participating in the Coupled Model Intercomparison Project Phase 5 (CMIP5), they calculated historic and future yearly extreme indices according to the definitions of the Expert Team on Climate Change Detection and Indices (ETCCDI). The global data set has a spatial resolution of 2.5°, includes the time period of 1861 – 2100 and is available for several global climate models. In this study the ensemble means of all global climate models for four different green house gas concentration scenarios representing an increase in the radiative forcing of +2.6 W/m^2 (rcp2.6), +4.5 W/m^2 (rcp4.5), +6.0 W/m^2 (rcp6.0), and +8.5 W/m^2 (rcp8.5) compared to pre-industrial levels of green house gases are used. While rcp2.6 represents a future scenario with an temperature anomaly of only +1.5°C, temperature increases of +2.4°C, +3.0°C and +4.9°C are projected for cp4.5, rcp6.0 and rcp8.5 scenarios (Moss et al., 2010). The data used is obtained from the KNMI climate explorer (http://climexp.knmi.nl/selectfield_cmip5_annual.cgi).

Results

Calibration

A logistic regression model is calibrated with data of 1189 questionnaire participants of which 593 migrated and 596 did not migrate. Generally, the model fits the data well (AUC = 0.88) and all predictors are statistically significant (Table 1).

Insert Table 1 about here

Individuals having a higher education or a family member that already migrated as well as individuals experiencing an extreme precipitation event show a tendency towards migration. On the other hand, individuals of an older age and individuals who experienced a drought event tend to stay (see figure 1).

Insert Figure 1 about here

Perception of extreme events

The occurrence of extreme climatic events is the main driver for our regression model. As described above, individual thresholds are used to distinguish extreme from non-extreme years. By comparing these individual thresholds with objective extremity measures (different percentiles) we can gain further insights in how migrants and non-migrants perceive extreme events. Figures 2 and 3 show the distributions of differences between what the individuals perceived as an extreme year and an objective measure of extremity (different percentiles of the reference period 1961-2010). These differences are classified according to their decision to migrate or not. Accordingly, negative values in the figures indicate an overestimation of the extremity of the year (they perceived the year to be worse/more extreme than it actually was), and positive values indicate an underestimation of the extremity of the year (they perceived the year to be less worse/extreme than it actually was).

Insert Figures 2 and 3 about here

Figure 2 shows that non-migrants perceived precipitation events as less extreme compared to the migrants' perception. While according to the majority of the migrants' perception an extreme year equals values above the 75th percentile, the majority of the non-migrants only considers years with values above the 90th percentile as extreme.

In contrast to heavy precipitation events, differences between migrants and non-migrants are very small with regard to the perception of drought events (Figure 3). The variability among the individuals' perceptions is small and both groups are pretty good in judging the extremity of a year. This can be explained by the very small variability in terms of droughts in the region. It seems that the occurrences of droughts are very stable over time compared to the changes in the occurrence of heavy precipitation. While the difference between the maximum and minimum of days without precipitation during the reference period is only about 20 days, the difference for heavy precipitation as expressed by days with precipitation above the 99^{th} percentile can be as high as 80 days.

Impact of climatic change

Except for the most moderate green house gas concentration scenarios (rcp2.6), all scenarios show significant (p=0.05) increases of heavy precipitation in the period 2011 – 2100 (Figure 4). While for the most pessimistic (in terms of radiative forcing) scenario rcp8.5 on average an increase of about 100 days compared to the individual thresholds is expected, the most optimistic scenario rcp2.6 does not project any increase.

Insert Figure 4 about here

In contrast to heavy precipitation, the projections of days without any precipitation tend to decrease, with two scenarios, rcp6.0, rcp8.5, showing a weak significant (p=0.05) negative trend according to the Mann-Kendall test. Additionally, here the differences among the emission scenarios are much smaller compared to the projections of extreme precipitation events.

To simulate the dynamics of the migration intention over time, the projections (r99p and r1mm) are applied to the logistic regression model. While the characteristics $(Age, Edu, HHmig)$ of the original 1189 individuals are kept constant, the occurrences of the climatic events ($Rain, Dro$) are changing with a yearly time step, with years showing larger values than the thresholds considered as extreme years and the ones showing smaller values considered as not extreme. Due to the decrease of the mitigating drought events and the increase of heavy precipitation events exacerbating the migration intention, the average proportion of migration among the individuals is increasing too.

Insert Figure 5 about here

Figure 5 shows that towards the end of the century the most severe scenario rcp8.5 reaches an upper boundary with a maximum number of migrants of about 730, as in this scenario hardly any drought events and almost constant precipitation events are projected for all individuals. The other scenarios show a less pronounced behavior. Nevertheless for all four scenarios a significant increasing trend at the 0.05 level is found for the period from 2011-2100.

Conclusion

Vietnam, due its geographic location, is among the countries most vulnerable to climate change impacts. In this paper we used a computational model, implemented using survey data and climate models, to explore the possible migration patterns in Vietnam due to climate chocks such as droughts and heavy rain (floods and cyclones).

Empirical results show that while migrants and non-migrants perceive long-term environmental events, i.e., droughts, in a similar fashion, migrants tend to perceive short/sudden environmental events, i.e., storms as more extreme compared to non-migrants. Moreover, we find that for all emissions scenarios, due to the decrease of the mitigating drought events and the increase of heavy precipitation events which exacerbate the migration intention, the average proportion of migration among individuals increases.

While our model offers an innovative way of understanding the relationship between climate change and migration, it represents only a partial picture of the potential impacts within Vietnam. This is based not only on the limitations in our approach, i.e., lack of time series data and interaction effects, but also on the inherent uncertainties in the climate scenarios. However, we believe that the approach to combine climate change projections with data on individuals' characteristics and perceptions of environmental can help shape understanding of potential future climatic impacts on migration decisions. Such understanding could be useful in generating adaptive policies and programs in the face of global environmental change.

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Table 1. *Results of the logistic regression model*

predictor	beta	SE	Wald	p	odds ratio
Constant	-1.30	0.5	6.78	9.2E-03	N/A
Age	-0.09	0.01	119.46	8.3E-28	0.92
Edu	1.05	0.11	90.56	1.8E-21	2.86
HHmig	0.55	0.17	11.14	8.4E-04	1.73
Rain	1.54	0.17	82.75	9.3E-20	4.64
Dro	-1.07	0.23	21.17	4.2E-06	0.34

Figure 1. *Modeled and observed average migration probabilities, classified according to the model predictors*

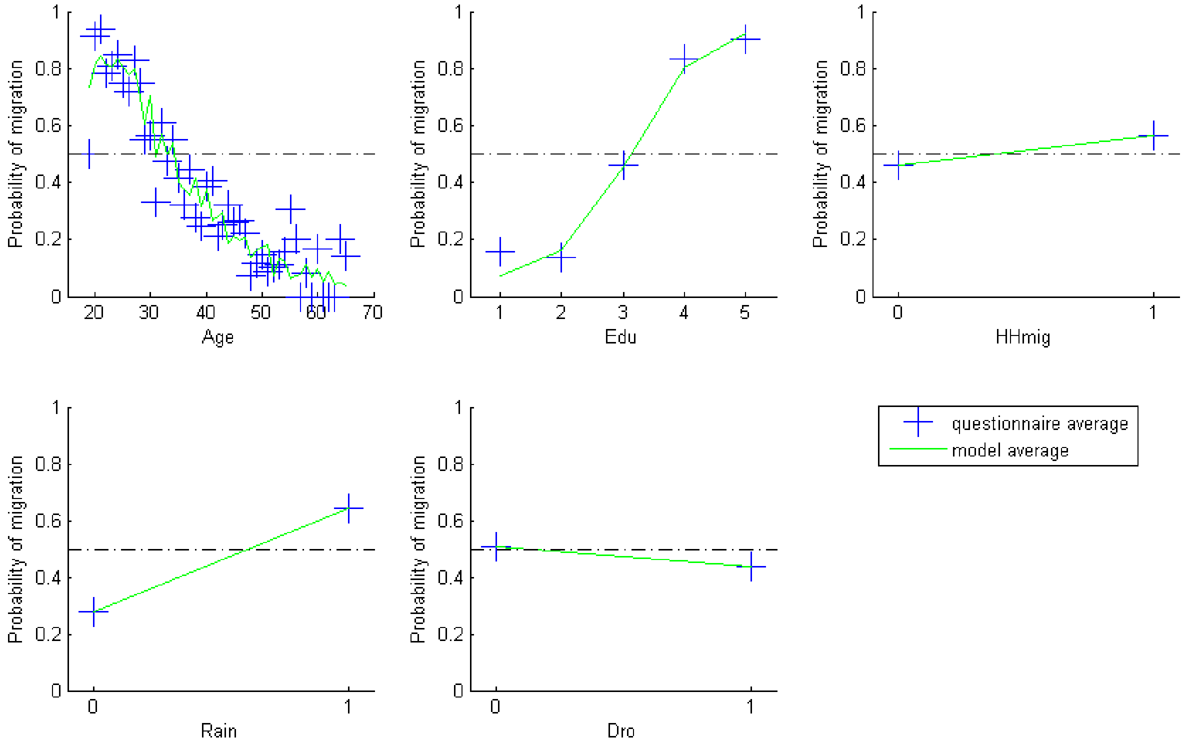

Figure 2. *Perceived extreme precipitation event minus actual extreme event as defined by different percentiles*

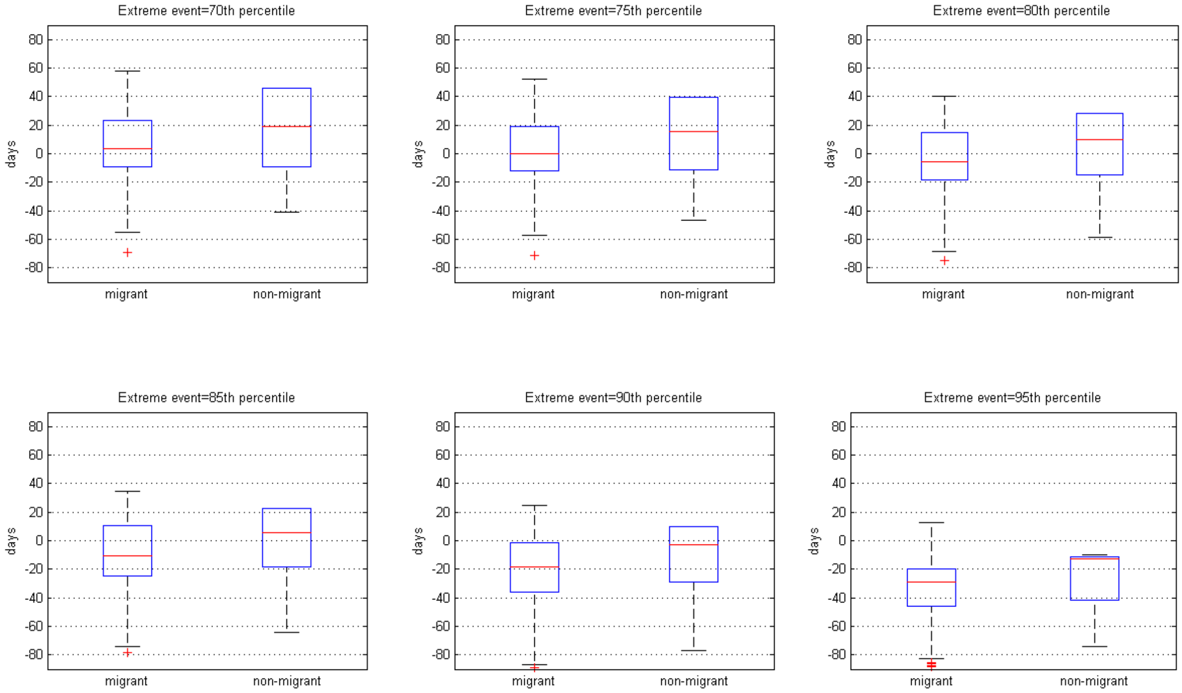

Figure 3. *Perceived extreme drought event minus actual extreme event as defined by different percentiles*

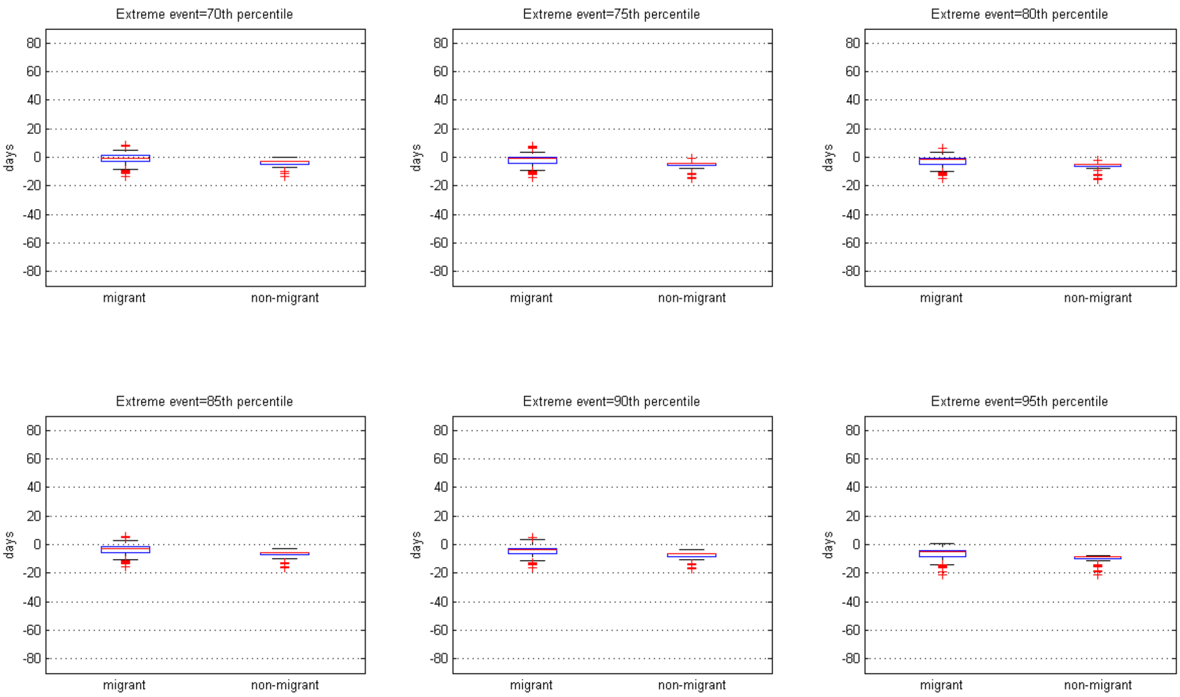

Figure 4. *Average over all individuals' locations ensemble mean r99p (top) and r1mm (bottom) above threshold for the period 1961-2100*

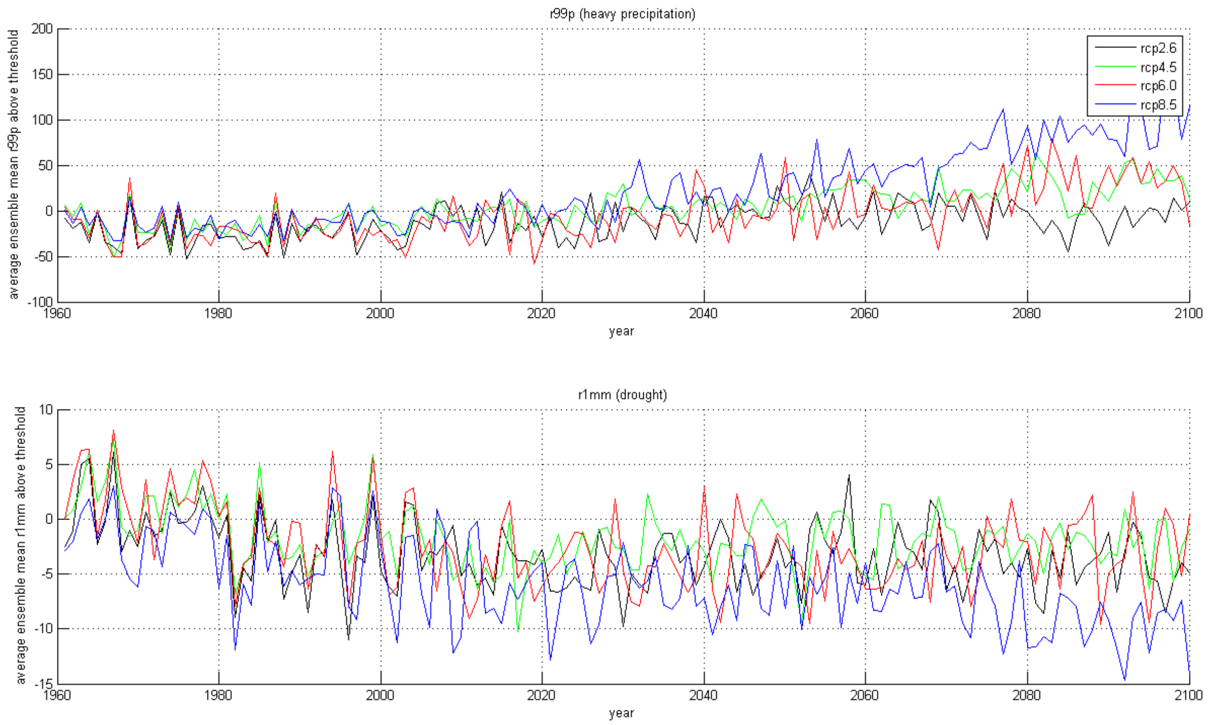

Figure 5. *Number of migrants for four green house gas scenarios (out of 1189 total individuals)*