Case study 10:
From hazards in Senegal to migrants' integration in the City of Paris

Lessons learned

Work Package 3 – Deliverable 3.4.10 (long version)

Delivery date: 30/03/2022

Dissemination Level: Public

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Lead beneficiary: Ramboll

Project full title: *Unpacking climate impact chains - a new generation of climate change risk assessments*

Project acronym: *UNCHAIN*

Grant Agreement number: *776608*

Project start date: *1st September 2019*

Funding scheme: *H2020-SC5-2016-2017*

Duration: *36 months*

Title	Date 30/03/2022
From hazards in Senegal to migrants' integration in the City of Paris: Lesson learned	
Project title	**Number of pages** 80
Unpacking climate impact chains. A new generation of action- and user-oriented climate change risk assessments (UNCHAIN)	
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Short summary

This document corresponds to the lessons learnt from the 10th case study implementation. The case study developed throughout this document addresses the question of transborder risks induced by climate change, with a specific focus on migration from Senegal and towards the City of Paris. The analysis, based on the Impact Chain (IC) approach, considers the interactions and implications between hazards occurrence, exposition, vulnerability, concluding on the socio-economic consequences of climate change and adaptation responses at local level.

Table of Contents

List of tables

List of boxes

List of figures

Introduction

This document corresponds to the lessons learnt from the 10th case study implementation. The case study developed throughout this document addresses the question of transborder risks induced by climate change, with a specific focus on migration from Senegal and towards the City of Paris. The analysis, based on the Impact Chain (IC) approach, considers the interactions and implications between hazards occurrence, exposition, vulnerability, concluding on the socio-economic consequences of climate change and adaptation responses at local level.

Both the reflexion and methodology are inspired by the *Vulnerability Sourcebook* (GIZ, 2017), which is a guide to the design and implementation of vulnerability assessment. The challenges in vulnerability assessment are to identify the current and potential hotspots, to identify the entry points for intervention, and to track potential changes in vulnerability. The *Vulnerability Sourcebook* method also enables to evaluate the effect of adaptation measures on vulnerability, through ex ante and ex post assessments.

The Impact Chains developed by the 2017 version of the *Vulnerability Sourcebook* are built around the components of climate-related risk identified by the Fifth Assessment Report (AR5), which are Hazard, Exposure (determined by its nature and level), and Vulnerability (determined by sensitivity and adaptive capacity).

Hazardous events are defined by the United Nations for Disaster Risk Reduction (UNDRR) as the "manifestation of a hazard in a particular place during a particular period of time" (2016). The essential criteria to categorize an event as a hazard is that it must present spatial and temporal components as well as the potential to affect a community, and that specific proactive and reactive measures must be available to address it, unilaterally or commonly. Distinction is made between environmental and societal hazards. While the firsts are described as arising "through degradation of the natural systems and ecosystem services upon which humanity depends", the seconds are considered as "brought about entirely or predominantly by human activities and choices, and have the potential to endanger exposed populations and environments". Societal hazards are therefore anthropogenic hazards, as they depend on human behaviours.

In the analysis of the IC between climate change related events and the integration of migrants in their destination economy, migration appears as a "compound hazard", which is a hazard triggered by another one. Hence, whereas the slow and fast onsets of climate change are considered as environmental hazards, environmental migration could be assimilated to a societal compound hazard, as it is triggered by climatic factors and perceived as a hazard by both the destination and origin countries.

However, the link between environmental factors and migration remains blurred, and the heterogenous results found in different papers let think that each effect is inscribed in a very specific place and period of time. Hence, these geographic and temporal constraints limit the external validity of the results. Moreover, as highlighted by Beine and Parsons (2014), the exercise of disentangling the effect of climatic factors from the effects of socioeconomic and political factors is delicate, if not impossible, "because climatic variations affect individuals' incentives to migrate and also their ability to do so". As climatic factors are replaced in the mobility arbitrage by the economic, social or political constraints they have themselves triggered, they disappear from the determinants and are integrated in their "compound" consequences. This part of the impact chain leads to consider climatic factors as not being the main drivers of migration (Alex and Gemenne, 2016). Through the conveying factors, beside the potential social and political instability caused by resources scarcity, the economic determinants, for their part, seem to be highly linked to the agricultural sector. Indeed, climate variations affect the potential future harvests, through for instance a disruption in crop growth or soil erosion and aridization (Dell and al., 2012; Compean, 2013; Burgess and al., 2014). Aggregated at the regional or national level, harvest failure can cause a negative impact on economic growth, estimated by Dell and al. (2012) to 1.1

percentage point of annual economic growth reduction for poor countries. As a consequence, mortality is also affected by the decrease in agricultural productivity and then the drop in agricultural income (Burgess et al., 2014). Combined to climate-induced water stress and demographic pressure, unprofitable agriculture is among the main determinants of food insecurity, which itself causes or maintains poverty. As poverty increases sensitivity and limits adaptive capacity, it is both the beginning and the end of this vicious circle, called poverty trap.

But before falling into this circles, individuals and households may get the time to arbitrate between adaptation options. Migration, either internal or international, appears as a major one in the context of climate change. Indeed, whereas extreme climatic events endanger the populations' physical security, and slow onsets threaten the financial one, migration represents both an escape lane and an income diversification option.

The recent literature formalizes the microeconomic arbitrage using the Random Utility Maximization (RUM) model, which describes the "*utility that an individual receives from living in a particular country compared to the expected utility received if moving to alternative destinations*" (Ramos, 2016[i]), choosing among a panel of countries. The RUM model's arbitrage integrates the time-specific costs (risk, financial requirement) and benefits (safety, perspectives of future income), as well as an individual-specific stochastic term, which distribution's assumptions determines the outcome (Beine and al., 2016 [ii]). In this arbitrage, climate change-related consequences are indirectly (and often unconsciously) integrated into the credit constraint, increasing its chances to be binding (Beine and al. (2016)[iii], Kaczan and Orgill-Meyer (2019)[iv]). If the costs overpass the benefits, immobility appears as the final outcome. However, if the benefits exceed the costs but the financial constraint restricts the scope of possibilities, this immobility is imposed by the simple incapacity to move (Black and al., (2011)[v], Kaczan and Orgill-Meyer (2019[vi])), which is called "migration trap".

Nonetheless, the precedent arbitrage may also result in a migration decision, the destination being selected by random utility maximization. After influencing the utility to leave one's own country, climatic factors may also influence, either deliberately or not, the utility of choosing one destination among others. In the case of environmentally triggered migrations, studies found that the main destination corresponds to the origin country, climate change engendering mostly internal displacements (Kaczan and Orgill-Meyer., 2019). Among these, cities appear as the attraction points, gathering 80% of the internally displaced populations (Mayors Migration Council). Internal migration might be transitory or definitive, depending on whether individuals and households get their desired living conditions, and whether they are capable to move again or not. In the context of climate change, Marchiori and Schumacher (2011)[vii] identify an indirect channel between rural areas' degradation and international migration, according to which rural to urban permanent movements would exert a downward pressure on wages, all else equal creating a greater incentive to move on an international scale, as the attractiveness of the origin country is reduced. The present work will exclusively consider the arbitrage leading to international migration, either transitional or definitive.

The destination is considered as "exposed to migration" relatively to its attractiveness, mainly composed by its income difference (Grogger and Hanson, 2011), diaspora (Beine and al., 2011), and migratory policy (Mayda and al., 1996, 2010).

Once migrants have reached their destination and obtained authorizations of stay, the challenge relies on their integration. This one is multidimensional, accounting simultaneously for the economic, social, residential, cultural and linguistic integration areas. However, the welcoming economies face many difficulties in the integration facilities they propose. The first obstacle can be constituted by the population of the destination country, which may fear immigration waves and worry for their own economic situation and stability. Indeed, migrants are perceived as "job thieves" by natives, a conclusion that has revealed erroneous (Card, 1990). Else than social tensions, barriers can raise from an initial strong pressure on the labor and housing markets, even before migrant's inflow. More globally tensions around national wealth can be felt, with a prevalence of poverty, increasing both the material and social difficulties to integrate the newcomers.

However, the receiving communities may also own and/or develop adaptive capacity, in order to improve migrant's integration as well as the global situation. Hence, the welcoming economies can deploy specific programs for housing capacities, social protection, food support, language courses… The common goal of these programs being to avoid non-integration or bad integration.

Case brief description

This case study considers the transnational risks of climate change through the specific analysis of migratory flows. Indeed, it is based on the impact chain linking hazards on agricultural lands to the departure of farmers from these unexploitable crops in Senegal. We consider the probability of occurrence of short and long determinant factors linked to climate change. We then take into account the specific exposure (in nature and level) and vulnerability (considering sensitivity and adaptive capacities) of the country toward climatic variations. However, the individual decision on the question of migrating or not and the possibility of movement offered by the environment (capacity to cover the cost of migration, capacity to move…) are still blurred and could not be deeply analysed in this work considering the absence of field survey. Moreover, most of the movements that occur for financial reasons and in a context where covering the cost of migration is complicated, migration tends to be internal before expanding to wider horizons. As we cannot consider this temporal shift through impact chains, we directly consider the link between climate change and international migration, keeping in mind that its realization can extend on one or few generations.

The focus is particularly set on the Senegalese population which would move internationally towards France, and more precisely towards the City of Paris. Indeed, Paris is acting in favour of the integration of the migrants that the City receives, deploying different programs and projects. Analysing the impact chain through which international migrations linked to climate (which may lead to more intense global migration waves) get integrated in a city as Paris, considering its sensitivity and adaptive capacity, would help find the entry point for future action, preserving or attaining a social, economic and urban equilibrium.

Meanwhile, it is essential to keep in mind that the processes illustrated through these impact chains only consider the movement in one way from Senegal to Paris, relying on multiple hypotheses. We acknowledge the limitations brought by both the geographic focus and the underlying hypotheses on unobservable factors.

Moreover, impact chains remain a very limited tool for climate risk analysis. Some of its limitations are underlined in this document, the most important being the simplification constraint implied by the illustration and search for corresponding indicators. Hence, it is primordial to perceive ICs as tools serving scientific research, more than seeing them as final objects.

Selected Impact Chain

The work led in this document gets its foundations on two impact chains. The first one considers the international migration decision for rural Senegalese, accounting for hazards' occurrence as well as the exposure and vulnerability components, the result of the individual arbitrage being migration (internal or international), or immobility (willing or trapped).

The second impact chain considers the integration process of international migrants, accounting for the exposure and vulnerability of Paris in the different dimensions allowing a full integration for migrants (economic, social, cultural, linguistic, residential).

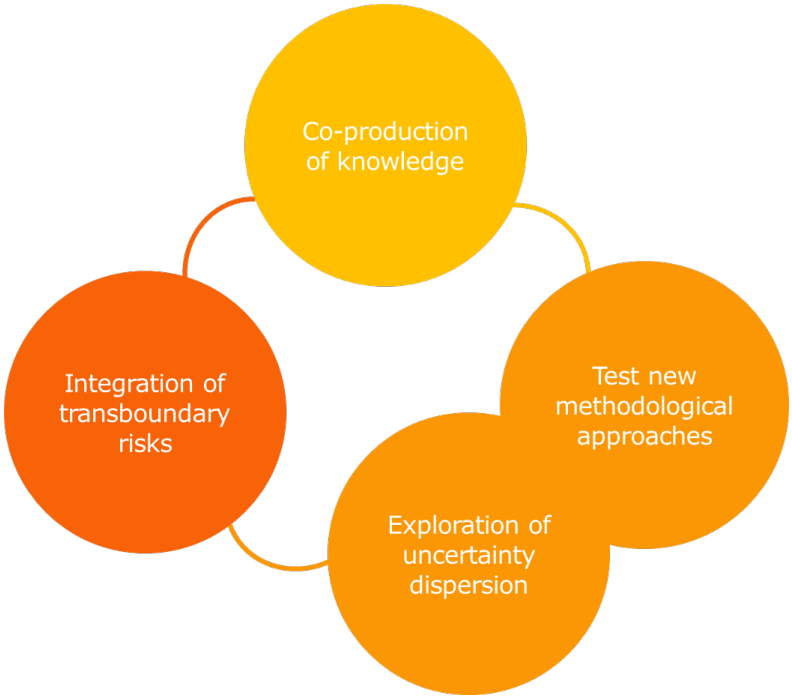
Innovation areas and research questions addressed

Co-production of knowledge appears as the major innovation addressed in the present case study, with stakeholders' consultation happening along the different phases of the process.

Moreover, the methods employed in the following development enable to test the sensitivity of the results and to compare the relevance of the different scores obtained in risk assessment, as well as the potential sources of uncertainty.

Finally, the present case study constitutes an analysis of transboundary climate risks, considering international migration triggered by environmental degradation.

Figure 1: Innovations brought by the case study



These innovations are integrated in the methodology following Table 1.

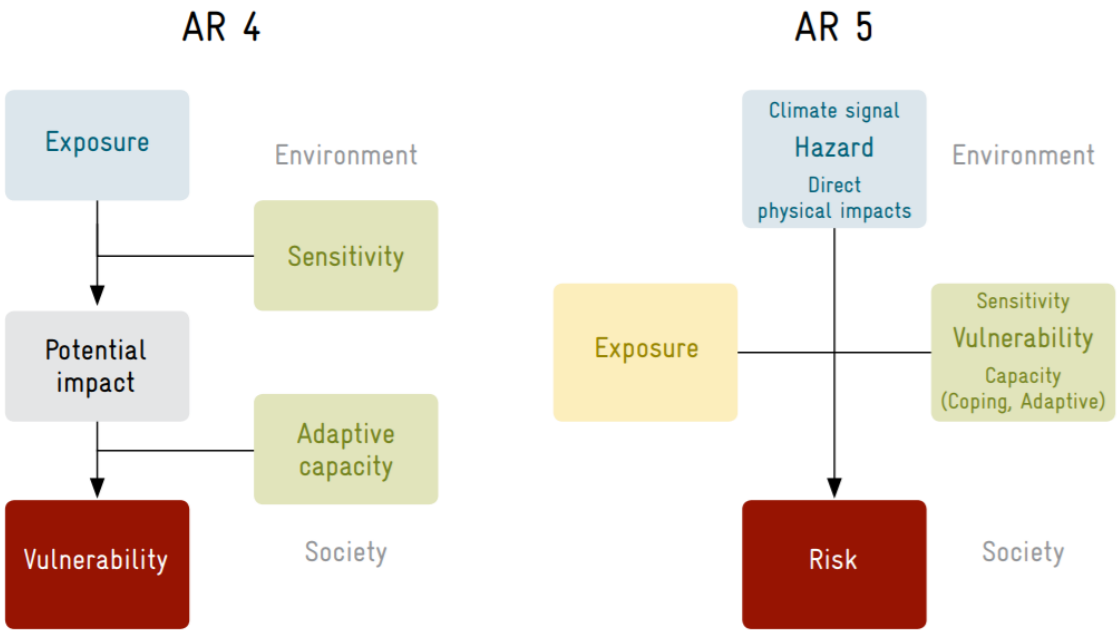
Table 1: Innovations treated along the methodology

Methodology's steps / Innovations	1. Prepare vulnerability	2. Develop impact chains	3. Identification and selection of	4. Data acquisition and management	5. Normalisation	6. Weighting	7. Aggregation	8. Results
2. Co-production of knowledge by implication and confrontation of the stakeholders, ownership for improved adaptation decision-making processes	X	X	X	X				X
4.a. Test new methodological approaches (quantitative/qualitative) within the Impact Chain framework for better integration of the dynamic aspects of transboundary risks						X	X	
4.b. Explore dispersion of uncertainty within the IC approach				X			X	
5. Expand the logic of Impact Chain by integrating transboundary impacts		X						X

1 Methodological approach to case study and related Impact Chain

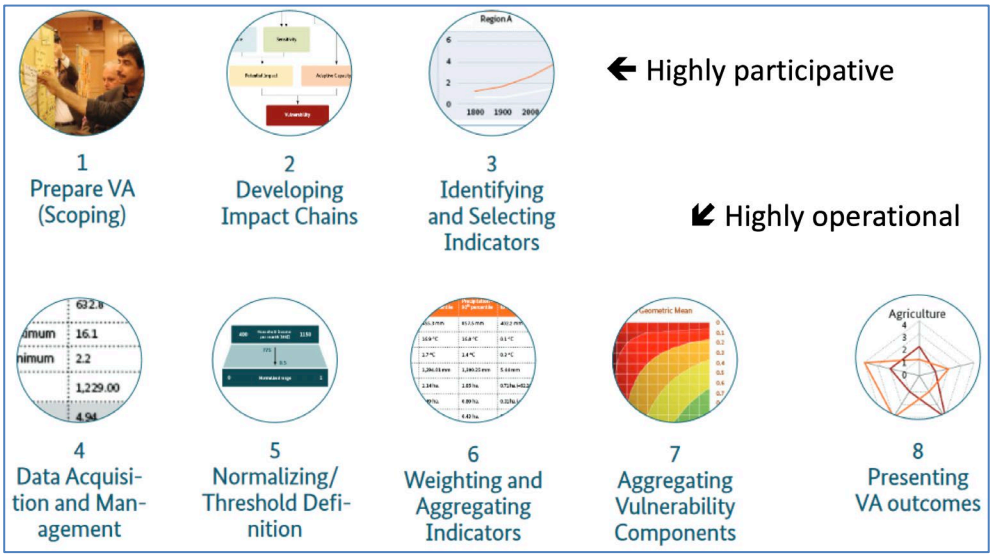
Impact chains constitute one among many methods aiming at climate risk assessment. It is important to keep in mind that, whereas the Fourth Assessment Report (AR4) from the IPCC relied on the concept of vulnerability as a final outcome, the Fifth Assessment Report (AR5) aims at accounting for the risk. Vulnerability is defined by "the degree to which a system is likely to experience or be adversely affected by the effects of climate change, including climate variability and extremes. Vulnerability depends on the character, magnitude, and rate of climate change to which a system is exposed, as well as its sensitivity, and adaptive capacity" (Parry et al. 2007). Besides, the AR5's notion aims at allocating more weights on the component of hazard. Risk then results of the interaction between vulnerability, exposure and hazard. Hence, the components, aggregation methods, and outcomes have changed between the two definitions of ICs (cf Figure 2).

Figure 2: Impact chains evolution (Risk Supplement to the Vulnerability Sourcebook, 2017)



The concept and definition of impact chains have been developed by the GIZ through the Vulnerability Sourcebook (2014, 2017). In the construction of the IC, we suggest here to follow the already elaborated modules (cf. Figure 3) to facilitate linkages with WP5 deliverable. However, we will highlight along this work the differences and potential methodological improvements proposed by the present case study analysis.

Figure 3: Vulnerability Sourcebook Modules



The Vulnerability Sourcebook methodology relies on eight consecutive modules for risk assessment implementation. While the first phases are highly participative, encouraging stakeholders' involvement for co-production of knowledge, the following modules are highly operational, creating incentives for methodological reflexions and improvement pathways.

1.1 Prepare Vulnerability Assessment

Box 1: Research questions and innovations adressed in Module 1

- **RQ1 : How to identify the relevant (social-ecological) system elements and their interrelations when doing impact chain assessment?**
  - RQ 1.1: How to better support identification of system elements / include knowledge from all relevant impact fields?
  - RQ 1.2: How to identify and consider interdependencies between climate change risks?
- **RQ3: How to integrate in the impact chain framework knowledge from other approaches already existing in literature on the normalization and aggregation phases and the definition of critical thresholds?**
- **RQ5: How to forward the impact chain approach from a 'linear' representation of risk components towards more system dynamics-oriented models?**

Main innovation: Co-production of knowledge

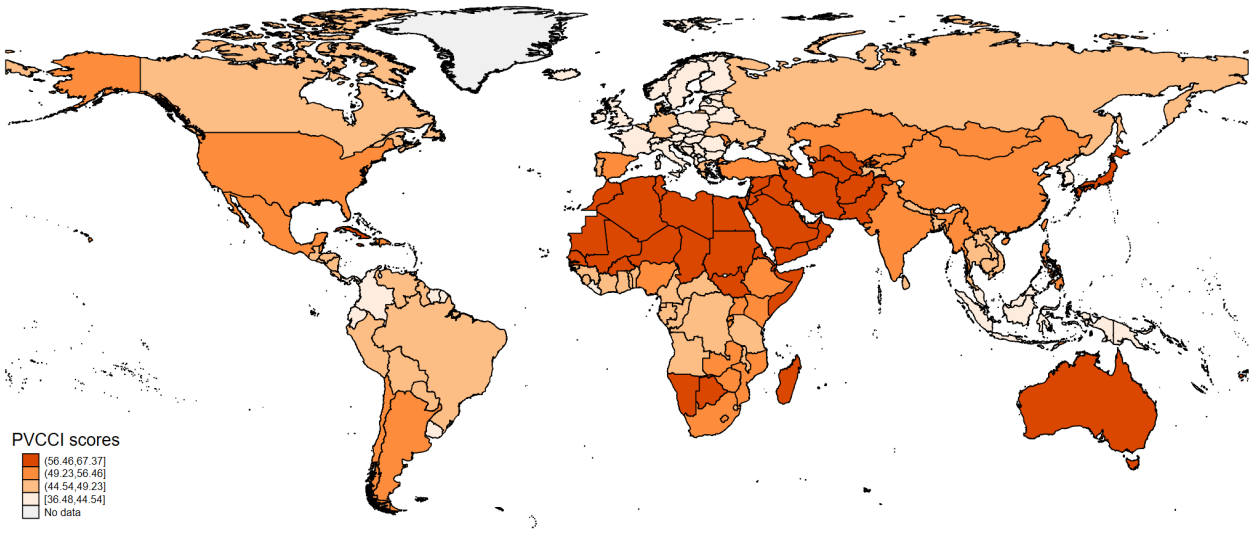
The assessment of vulnerability requires a clear definition of system boundaries (1.1.1), in order to know what is considered and what is excluded from the analysis. Then, in a country-specific approach, the Senegalese vulnerability context (1.1.2) and French the one (1.1.3) are analyzed.

Finally, we explore the potential data sources available for the quantitative and qualitative analysis (1.1.4).

1.1.1 Definition of system boundaries

Vulnerability assessment first requires the system to be well defined. The present case study focuses on transborder migration between Senegal (at the national scale) and the City of Paris (at the communal level). This specific focus is justified by the important colonial and diasporic links between Senegal and France, this European country standing for the second favourite destination country for Senegalese[1], after Gambia, which is easily substantiated by distance. The **geographical frame** of the study hence establishes link between very different entities, in terms of size (geographical area, population, economic weight), location, and environmental characteristics. Whereas Senegal appears as a developing country, particularly vulnerable to climate change, Paris, which is the French capital city, seems blessed, presenting a low physical vulnerability score (cf. Figure 4).

Figure 4: Map of physical vulnerability to climate change (PVCCI)



Elaborated by the author, based on quadratic PVCCI (FERDI) and World Bank map

In terms of **concerned population**, a specific focus is made on rural Senegalese, who tend to depend more on the agricultural sector, which appears as the most vulnerable to climate change impacts. This physical vulnerability makes from farmers a stock of potential migrants, searching for income alternatives. Any focus is made on particular gender, level of education, or other individual characteristics. Concerning the City of Paris, the global Parisian population's and immigrants' features are considered. The framing on Senegalese immigrants while rely more on qualitative than quantitative analysis. Moreover, as the climate-related motivations that intervene in the migration decision are impossible to disentangle from economic and political purposes, we

[1] Considering the 2017's migrant stock.

consider the integration of all immigrants, environmental migrants being impossible to identify accurately without field surveys. Once more, any focus is made on particular gender, level of education, or other individual characteristics.

Finally, the present work aims at assessing the agricultural households' vulnerability in origin country as well as the one of migrants' integration systems in the destination economy.

1.1.2 Senegalese vulnerability context

- **Physical vulnerability**

West Africa is among the most affected areas due to the vulnerability of key development sectors in its countries. Regarding Senegal, the country is already facing high climatic risks due to its geographical position and economic vulnerability. The main effects of climate change are mostly observable and characterized by an increase in extreme climatic hazards such as droughts and meteorological events, floods, and a great variability in the length of rainy seasons and even thermal seasons.

According to studies conducted on the consequences of climate change2, Senegal has experienced a decline in average rainfall since the 1950s. This trend is expected to become more important by 2040, with extreme events varying between -30% and +30%. In Dakar, the drop in rainfall is expected to be 50%, while it would be 7% in Kédougou, south-east3. Moreover, this trend has a heavy impact on one of the key activities of the Senegalese economy, the agricultural sector, which depends on rainfall, as well as on the country's water resources and coastal areas. This temporal disruption of the rainy season has been underlined by the interviewed stakeholders and agricultural experts. Parallelly, the intensity of rainfall has increased, leading to extensive and frequent flooding in Senegal's urban centres.

Other consequences of climate change are also visible at the country level and tend to intensify, with an increase in average temperatures of +1.1 to +1.4°C expected for 2040; mainly during the three traditionally hottest months of the year. Between 1960 and 2010, the temperature increase was observable in all the country's weather stations, with regional variations depending on the climate zone. Through the country, temperatures have already risen by 0.9°C since 1975 4, contributing to the amplification of the effects of drought. According to the stakeholders and experts, in addition to soil deterioration, this trend in temperature also impacts populations in terms of health and productivity, especially concerning pastoralism. Aridization, combined with salinization, engenders a lack of soil nutrients.

Moreover, a rise in sea level, water temperature and salinity are expected. Indeed, since 1880, the sea level has already risen by 20 cm and an increase of 30 to 122 cm is predicted by 2100 for Senegal. Finally, disruptions in the availability of water resources are to be expected.

[2] Data from the National Agency for Civil Aviation and Meteorology (ANACIM)

[3] Ecological Monitoring Centre (CSE), 2010

[4] FUNK C., ROWLAND J., EILERTS G., ADOUM A. et WHITE L. (2012) - A climate trend analysis of Chad. Édit. U.S. Geological Survey, fiche descriptive 2012-3070, 4 p

Figure 5: Climate change scenarios for Senegal by 2040 by geographical area (in mm and °C)

	Scenarios	North	South-East	South-West	Centre-West
Rainfall	RCP4.5	-16	-89	-89	-89
	RCP8.5	-8	-61	-61	-61
Temperature	RCP4.5	+1.18	+1.17	+1.17	+1.17
	RCP8.5	+1.41	+1.37	+1.37	+1.37

Source: ANACIM, 2016

Coupled with the overexploitation of natural resources, the combined effects of anthropic pressure and climate change, a degradation of the physical environment, ecosystems and a loss of biodiversity are to be expected.

All these trends have had, and will continue to have, a major impact on the key activities of the Senegalese economy that are directly or indirectly affected by climate change. Studies[5] have shown that the agricultural sector (livestock and forestry sub-sector), coastal areas, water resources, fisheries, tourism and health are the most vulnerable sectors.

➢ Socioeconomic vulnerability

From a socio-economic point of view, 60% of the Senegalese population depends directly on these fragile ecosystems for their livelihoods. Climate change is seen as a risk that could "worsen the already mixed performance of agriculture"[6], which contributed to GDP for 17,5% in 2015[7]. In Senegal, this sector mobilizes almost half of households (49.5%) and is highly dependent on climatic conditions, with 61% of households practicing rainfed agriculture. In a context of deficit and rainfall variability, agriculture remains very vulnerable, and yields are increasingly low. The effect of climate change on the agricultural sector will also have severe impacts on food stocks and availability. Indeed, food stocks, constituted during harvests, are not important enough to cover the needs of the rest of the year. In addition to the decrease in quantity, stakeholders also highlight the deterioration in food quality. As a consequence, the prevalence of malnutrition is still high on a national scale. A recent SMART nutrition survey (2008) has analyzed a worrying situation in several regions due to soaring food prices. This survey has concluded that acute malnutrition has exceeded the nutritional crisis threshold of 10% in 10 of the 13 districts[8]. Access to food for poor households has indeed become increasingly difficult over the past three years.

The Nationally Determined Contribution (NDC) mentions that 2.5 million hectares, or 2/3 of Senegal's arable land, is already considered degraded and the acceleration of degradation could

[5] PANA, 2006.

[6] NDC agriculture

[7] https://agriculture.gouv.fr/senegal

[8] OXFAM, Interim Report "Analysis of the poverty context in Senegal", 2009.

lead to a decrease in yields for both agriculture and livestock. The NDC reports a 30% decrease in cereal production by 2030 due to the combined effect of a decrease in rainfall and an increase in potential evapotranspiration of around 5% in the case of a 4°C scenario.

Thus, the consequences of climate change may compromise the country's development efforts and plunge the rural world into a situation of poverty, as well as social and health insecurity.

➢ Political commitment

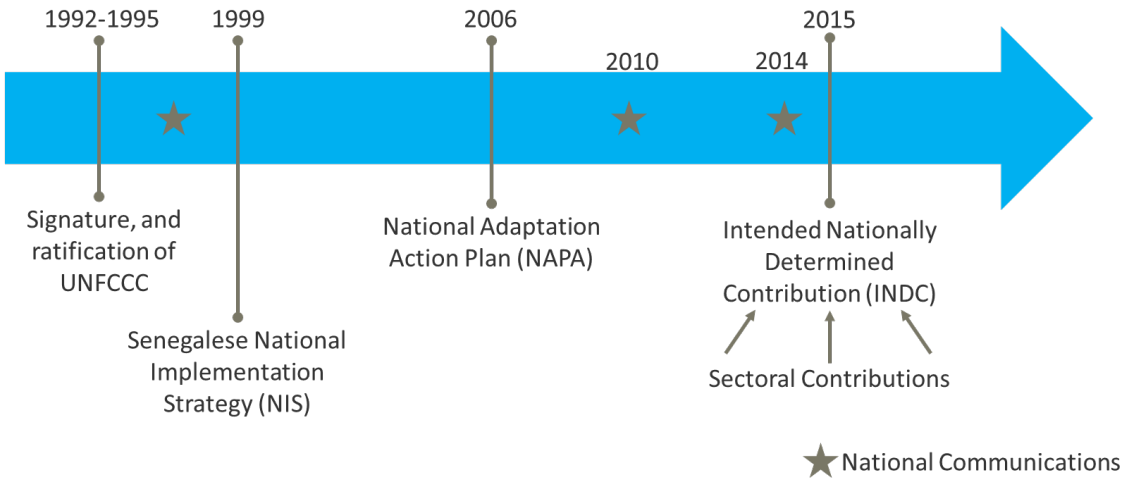
In its strategy to cope with the adverse effects of climate change, Senegal has signed the United Nations Framework Convention on Climate Change (UNFCCC) on 13 June 1992, ratified it on 17 October 1994 and entered into force in January 1995. The first greenhouse gas (GHG) emissions inventory was conducted in 1994 by the Ministry of the Environment.

These commitments highlight the country's willingness to contribute to the intergovernmental effort to fight global warming and its impacts. This willingness is also marked by the elaboration of several reports and reference documents at the national level, the improvement of the institutional framework, the implementation of projects and programmes for mitigation and adaptation to climate change.

To achieve the set objectives, a National Implementation Strategy (NIS) was developed in 1999. In 1997, Senegal also presented its first National Communication; two others followed in 2010 and 2014. In 2006, the first National Adaptation Action Plan (NAPA) was developed. Moreover, Senegal was also among the first African countries to submit its second national communication to the UNFCCC Secretariat in 2010.

Furthermore, in 2015, prior to COP21 in Paris, Senegal submitted its Intended Nationally Determined Contribution (INDC) and its Third National Communication. Sectoral Nationally Determined Contributions (NDCs) have also been developed in order to contribute to the national NDC (process currently underway). These NDC present the precise commitments to reduce greenhouse gas (GHG) emissions defined by Senegal by 2035 on the mitigation side. It also expresses the set of major measures necessary for adaptation to the adverse effects of climate change.

Figure 6: Political involvement in climate change adaptation and mitigation through time

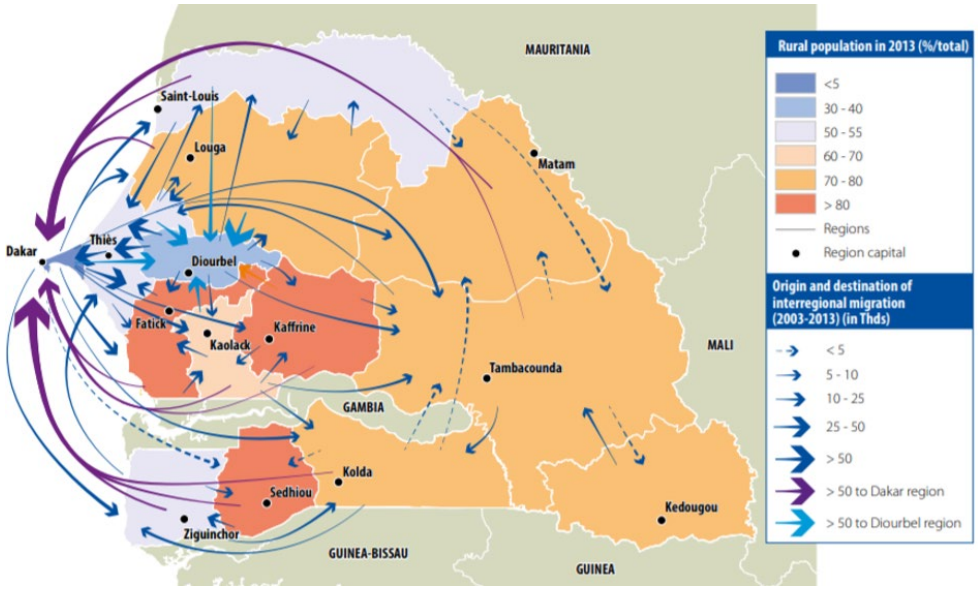


In the project stakeholders' eyes, climate change is well integrated in the political strategy, but the indicators and logical frameworks used for monitoring can still be improved. Generally, the obtained results seem inferior to the expected ones.

➢ Migration

In the context of environmental degradation, migration tends to be mostly internal. Indeed, as distance constitutes one of the main monetary and non-monetary cost of migration, movements tend to be geographically limited. In Senegal, the stock of potential migrants is mostly constituted by young men searching for employment, standing for an exceeding labor force. Hence, regarding rural unemployment and poverty, the prevalence is to rural exodus, with Dakar standing for the main destination (cf. Figure 7).

Figure 7: Migration flows between regions



Source: Ba, Bourgoin, Diop

However, some individuals also choose to cross borders, either to reach a contiguous or further country, becoming international migrants. According to François Gemenne, it is important to keep in mind that these international movements often comport internal backgrounds, which did not bring the expected results, making from international migration a "last best option". This migration expert also underlines the importance of the social and sociological aspects of migration, considering the will to "honor the family", to "reflect a golden appearance" or even the attraction for a wider and more diversified "market for wives", when considering males' movements from tiny rural villages towards developed countries.

This migratory question is eminently political and tends to engender different responses from the governments. In the case of Senegal, there are no real restrictions to emigration from the governments but caritative organizations try to sensitize potential migrants to the risks of migration, trying to deconstruct the previously built myth.

Whereas migration tends to present immediate costs and long-term gains for the destination country, it also engenders consequences for the origin country. Indeed, the main issues of migration are shortages in labor force, brain drain, loss of tax contributors, potential mothers and fathers... In the case of environmentally-triggered migration, the question of brain drain is relatively discarded, as the potential migrants tend to be rural and low educated populations. Moreover, considering the youth and impressive growth of the Senegalese population, and the fact that the ones who move tend to be the unemployed ones, in other words the "excedent of labor force", there are no heavy consequences of migration flows on the labor market's equilibrium. Besides, even when migration takes place, these rural migrants tend to occupy low positions in the urban informal market, often with high risks and no protection.

As a compensation of the loss constituted by departure, the families left-behind in the origin country tend to receive remittances from their migrant(s). According to studies, the main use for these cash transfers is the compensation of the migrant's absence as a parent, and do not always show desirable effects on education and participation to the labor market. In the case of Senegal, remittances constitute a very important inflow of capitals, often called the "migrants' bank". The underlying risk for the origin country hence become the development of a dependency to these remittances.

1.1.3 Parisian vulnerability context

Facing immigration waves, the City of Paris struggles for insuring migrants' integration as well as natives' and migrants' security. The intensity of this struggle often depends on the elected wing.

The name of the City of Paris makes it appear as a pole for activities and potential occupations.

- **Identified weaknesses**

In 2017, the International Rescue Committee related the situation of migrants and refugees in its report "Resilient Paris: Recommendations brief". The main extracts are that "displaced face safety issues unique to their situation that place them at risk of violence, discrimination, abuse, exploitation, and other harms", "the current response lacks a comprehensive approach […] that could support both short-term social cohesion and the long-term inclusion of the displaced population". The report also underlines that displaced population "share needs with vulnerable Parisians" (housing and employment). The final conclusion is that "the City of Paris's response to the influx of displaced populations is comprised mainly of activities related to reception and documentation of displaced persons, and lack a more thorough assessment to link with appropriate supportive services", in addition to a "lack of training on working with displaced populations, particularly refugees and unaccompanied minors, and a lack of monitoring to ensure adequate provision and follow up".

The City of Paris admits its difficulties concerning the integration of new migrants in the health and education systems, as well as the management of "invisible populations", which stay in precarious situation because no regularization is possible for their situation.

- **Political interest and social tensions**

A problem that is often raised by migration waves concerns the social stability, as politics tend to use the fear as an election argument. It is not scarce to hear about "invasions" or "replacement"

by migrants, as well as cultural fading. Another notion is the "air draft", according which the integration of the arrived migrants would incentivize the potential future migrants to opt for the same destination, leading to uncontrolled waves. However, this notion seems to be unrealistic when considering that inflows continue whether the migrants are integrated or not.

Besides, ethics impose an integration in dignity for people in need, as well as a minimization of the potential negative impacts on natives. In this context, the current mayor of Paris' will is to protect both migrant and administered populations. The question of climate migration is already on the desk of the city hall since 2012. The current action is two-fold. The first goal is to mitigate the global impacts to maintain an international political stability. Once arrived in their destination, the second goal is to integrate migrants as well as possible (following the IOM policy), for their dignity and in order to mitigate a potential feeling of resentment.

- **Initiatives**

A famous initiative around the question of migration towards the City of Paris has been "Le Bulle", a "spacer site"9 in the City where space was unoccupied and hence offered for a delimited time to the integration organization. La Bulle was a center for first welcome, allowing to limit the settlement of precarious campsites, and testifying in favor of the settlement of similar camps along the migratory roads. Indeed, the experience showed positive results as well as an important involvement from local populations.

It seems that, when migrants are oriented towards areas with potential activity, they tend to accept moving. Hence, according to Julie Roussel, project manager of the mission Adaptation to climate change, it is necessary to create bridges between territories and cities to fluidify the distribution of migrants and refugees. This integration should not wait for European decision and should better start now. Moreover, the inflow of labor force in the rural areas raises the idea of a new development of the agricultural sector.

Besides, Paris is currently involving in the Mayors Migration Council, among other large cities, to improve the share of good practices at the local level.
The global goal is to make from migration an opportunity instead of a risk, but for now no real public policy has been implemented in this end, as the reflection is still strategic. The multiple organizations and departments trying to implement integration devices are often limited by a lack of financial means. Indeed, there is no specific budget allocated to the different initiatives, which only benefit from subsidies from the City of Paris.

1.1.4 Identification of data sources

Relevant information is available through literature concerning both climate change and migration. Moreover, the literature concerning the link between the two notions has been growing during the last two decades, providing many elements.

Since the Conferences of Parties (COP) lead governments to write commitments for their mitigation efforts, national communications and adaptation plans are publicly available for information and monitoring. Experts from the International Panel for Climate Change (IPCC) also

9 Transitory area before the settlement of a project for which the administrative procedure is very long.

report major and most relevant information. Besides, the crescent interest and ability for measuring climate change induced the development of many databases as CCKP, Thinkhazard!, IPCC DDC (Data Distribution Center), UNDP CCCP (Climate Change Country Profile), Permanent Service for Mean Sea Level (PSMSL) and the Socioeconomic Data and Applications Center (SEDAC) as part of NASA's Earth Observing System Data and Information System (EOSDIS).

Finally, some platforms allow for the improvement of information availability, as CI-grasp (Climate Impacts: Global and Regional Adaptation Support Platform) and CIP (Climate Information Portal).

Concerning migration, bilateral matrixes of migrant stocks have been elaborated (Ozden and al., 2011), even if their accuracy remains fragile, population flows being much harder to measure than goods.

1.2 Developing impact chains

Box 2: Research questions and innovations adressed in Module 2

- **RQ1: How to identify the relevant (social-ecological) system elements and their interrelations when doing impact chain assessment?**
  - RQ 1.2: How to identify and consider interdependencies between climate change risks?
  - RQ 1.3: How to draw clear causal links between climate signal and impact / actual risk to the investigated asset?
  - RQ 1.4: How to support methods for result evaluation?
  - RQ 1.6: How to identify potentially beneficial vs. potentially problematic interdependencies?
- **RQ5: How to forward the impact chain approach from a 'linear' representation of risk components towards more system dynamics-oriented models?**

Main innovations: Co-production of knowledge and integration of transboundary risks

The development of impact chains heavily relies on the contexts described in Section 1.1, combined with stakeholders' involvement for their modification and validation. We first elaborate the impact chain linking climate hazard in Senegal to international migration (1.2.1), then explore the transition between both impact chains (1.2.2), and finally establish the impact chain related to migrants' integration in the City of Paris (1.2.3).

1.2.1 From climate change in Senegal to international migration

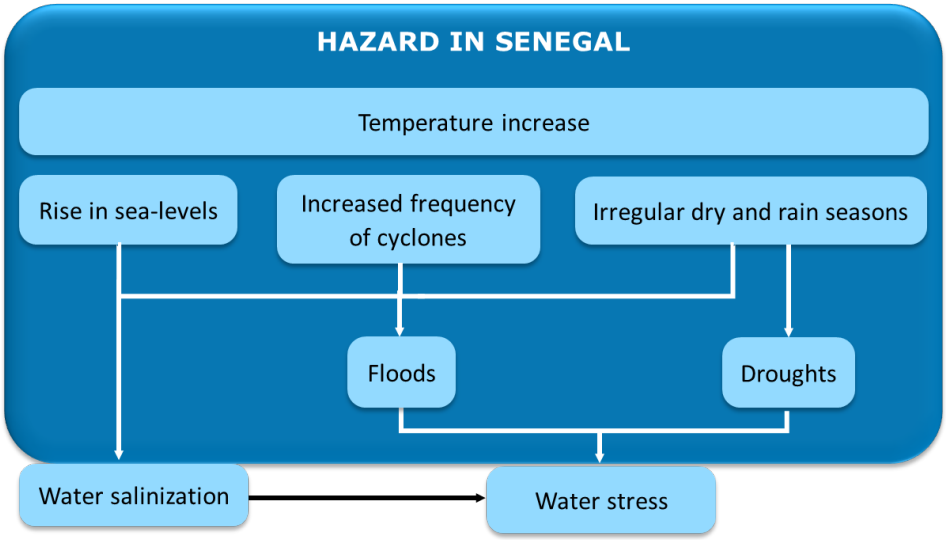
Following the AR5 definition of IC, we progressively analyse the components of hazard, exposure, and vulnerability, combined with narratives issued from stakeholders' consultation and literature.

- **Hazard**

As mentioned in Section 1.1.2, the physical vulnerability of Senegal is mainly constituted by temperature increase and its consequences. While one of them is the dilatation of water, which may lead to rise in sea-levels, temperature also influences seasonality disruption. Whereas the rise in sea levels is hardly tangible yet, unless through water salinization, seasonality is highly felt by

rural populations, according to stakeholders. This irregularity manifests for instance through a delay in the rain season beginning, crossed with an intensification of rainfall. Rural areas are then affected alternatively by floods and droughts, leading to water stress.

Figure 8: Hazard in Senegal

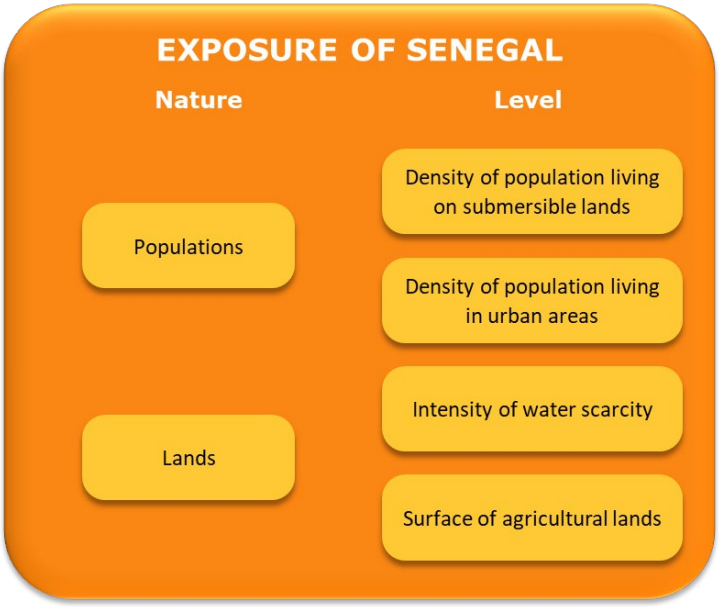


- **Exposure**

The nature of the Senegalese exposure is defined by both affected populations and affected lands. Indeed, the rise in temperature threatens both health and safety of exposed populations, with death as an extreme consequence (Burgess and al., 2014). The intensity of this exposure depends on the density of population living on submersible lands as well as urban density.

Besides, agricultural and urban lands are threatened by erosion and floods, leading them to be unsuitable for housing and agricultural activities. These adverse effects are felt approximately proportionally to the surface of agricultural lands and the level of water scarcity.

Figure 9: Exposure of Senegal



➢ Vulnerability

Following the IPCC Fifth Assessment Report (AR5), vulnerability is composed by the sensitivity of the system and its adaptive capacities.

○ *Sensitivity*

Senegal's sensitivity in facing climate change is first determined by its poverty context. Indeed, poor populations tend to be the most affected by climate change, and the most limited in terms of adaptive capacities. These populations are mostly rural, highly dependent to agriculture, and then highly exposed to production's variations. Moreover, climate-smart agriculture is not yet widely spread, despite the multiplication of projects aiming at the elaboration and dissemination of resilience practices. Considering the lack of alternatives that rural households face in terms of income sources, often linked to a low level of human capital or opportunities' scarcity, they tend to rely heavily on agriculture, making them even more vulnerable to climate change impacts.

Similarly, on a national scale, Senegal would be about proportionally sensitive to climate change than its gross domestic product (GDP) depends on agricultural value added (VA). Indeed, agriculture-dependent economies tend to be particularly vulnerable to climate change impact, which could threaten the entire GDP. In addition to economic issues, climate change can lead to systemic problems, through resources scarcity and food insecurity, which threatens simultaneously public health, social stability, and economic productivity. An apparent solution for an economy would be to rely on food imports, which actually constitutes a trap of future dependency to the exterior for fundamental goods.

○ *Adaptive capacity*

Senegal disposes from a panel of adaptive capacities, elaborated at different scales, but presenting different level of development and efficiency. Governance constitutes a major pillar, with the

necessity for political stability as well as environmental commitment either to implement or at least not to intervene as an obstacle in the implementation of specific policies and programs. Many projects have been elaborated by internal and/or international forces, aiming at improving agricultural resilience. For instance, researchers from the CCAFS (Climate Change, Agriculture and Food Security) are deeply working on agriculture-related projects, like the USAID/CINSERE project, aiming at the diffusion of climate information. Its objectives are to improve information production, to develop dissemination channels, to form producers to be able to understand and use the information, and to assess the impacts of the dissemination on producers' incomes.

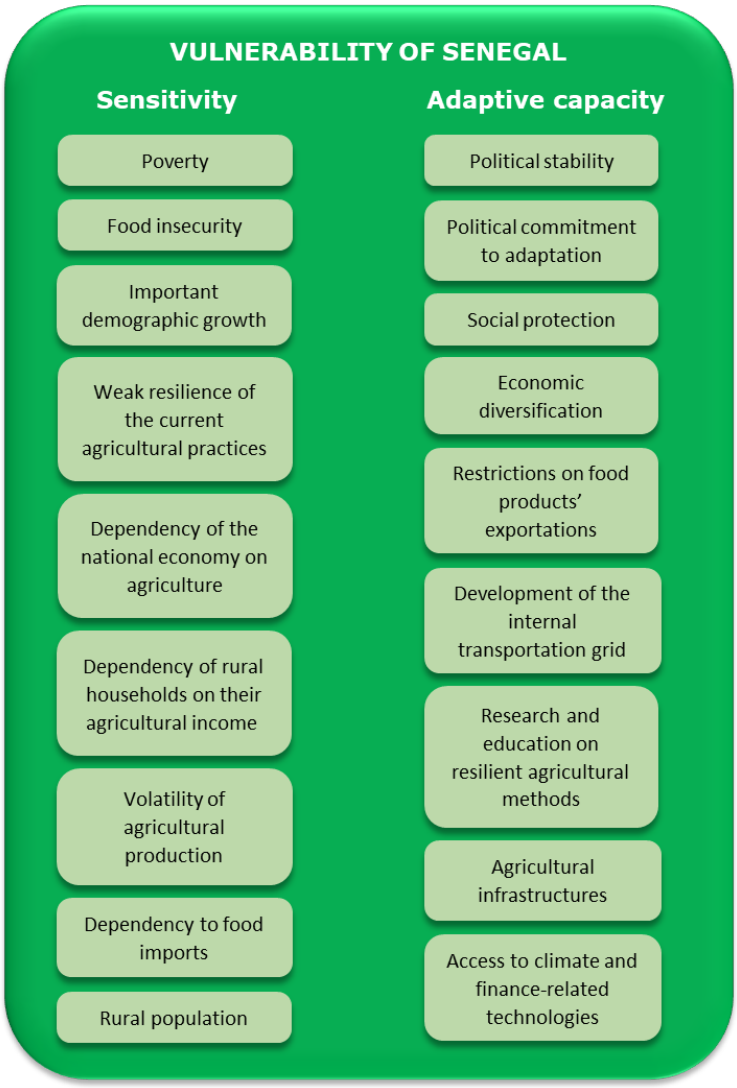
Besides, Senegal is settling climate-smart villages, where practices are experimented as pilot before extending them to higher scales. These villages also comport social aspects, with the creation of nature-related jobs, awareness campaigns and empowerment missions oriented towards young populations, which are the major profiles of potential migrants.

Another aspect that benefits from many national and international projects concern the development of insurance and financial services specific to the agricultural sector, offsetting the potential loss of harvests.

Parallelly, governments may have the capacity to partly compensate socioeconomic sensitivity by implementing social protection actions, acting as "safety nets" and avoiding the fall into poverty traps. These actions however need to be combined with job creation programs, and, as possible, with a political aim of economic diversification, in order to disseminate the risks. Moreover, the development of infrastructures, especially concerning the transportation grid, may enable populations to gain flexibility regarding distance, then accepting geographically further jobs without the need to migrate.

Finally, governments can act through regulation, opting for a protective policy prohibiting food exportations. This kind of intervention can appear as an adaptive capacity but actually presents many limits.

Figure 10: Vulnerability of Senegal



- **Other components**

Working on migration, we cannot limit our analysis to climate-related, geographical, economic and political parameters. Indeed, migration is a human decision that results from an arbitrage integrating many factors. In a context of environmental degradation, migration appears as an adaptation option. Facing the adverse effects of climate change, that are felt through the economic transmission channel for rural populations, households tend to search for alternative sources of income. Hence migration appears as one of them. In a context where information is at least partly available, the microeconomic arbitrage realized by individuals or households considers both the costs and expected benefits linked to migration. These costs and expected benefits constitute the "push" and "pull" factors of migration. "Push" factors correspond to all parameters that can incentivize an individual to leave his country, whereas "pull" factors correspond to the parameters of the destination's attractiveness. Among them, we find macro-level factors such as political (in)stability (conflict, violence, political system…), economic environment (unemployment,

opportunities, living standards…), demographic (median age, population growth, ratio of dependence…) and social (social welfare programs…) conditions, as well as environmental parameters (soil quality, precipitations…). The importance of political, cultural and economic contexts, which determine vulnerability and may deter or foster migration have already been identified in the literature (Black and al. (2013[viii]), Waldinger (2015)[ix]).

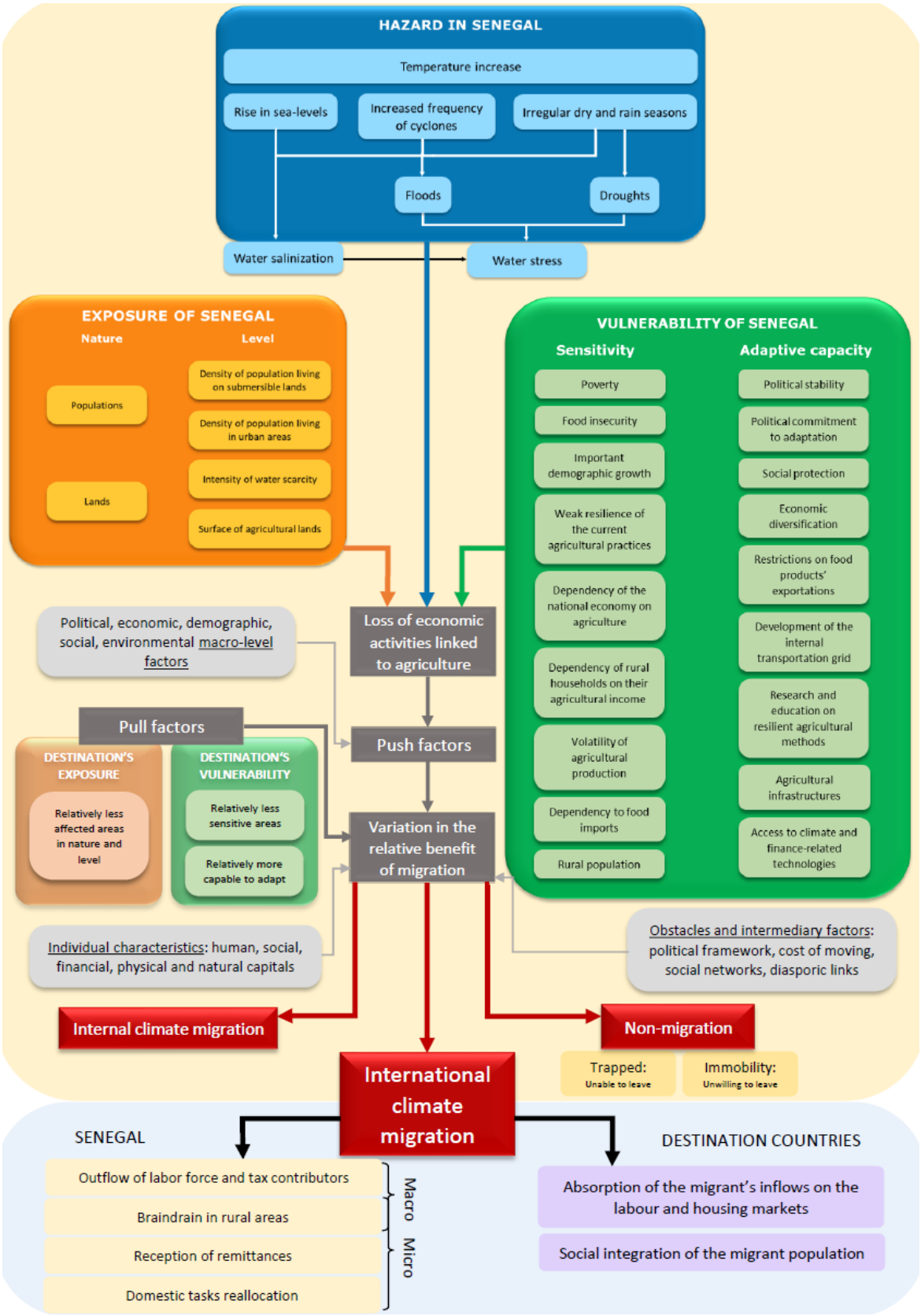
To this panel of dimensions entering in the migration decision, individual and country-specific reactions must be added. On the one hand, the migration decision, either taken by the individual or by the household, integrates observable (age, education, gender…) and unobservable (talent, influence…) individual characteristics. On the other hand, whereas the origin country rarely retain emigration, destination countries often establish strict immigration policies, which can completely deter migration if this one is not a question of survival. Among the other costs of migration appear monetary costs (passport, transport…), non-monetary costs (remoteness from family and friends, mental burden…) and the risks of migration (failure, death…).

The microeconomic arbitrage can hence result in non-migration, if the costs overpass the benefits (willing immobility) or if the household is forced to stay (trapped). As the microeconomic arbitrage is impossible to perceive on macroeconomic scale unless the decision is to migrate, these potential migrants who finally decide to stay are imperceptible. Concerning the rest of migration, a high majority is internal, limiting its costs, as presented in Section 1.1.2.

Finally, when the decision's outcome is to migrate internationally, high consequences on the origin and destination countries are to be expected, in proportion with migrant flows. Concerning the origin country, here Senegal, emigration flows stand for an outflow of labour force and tax contributors. In the case of educated individuals' emigration, we refer to "brain drain". However, it is important to keep in mind that, in the context of emigration from rural areas, which often correspond to the least developed ones, the phenomenon of brain drain is limited. Yet, another phenomenon that takes importance in the case of rural migration is the reallocation of domestic tasks and powers among the household members, whether one of them migrated or the entire household moved. Last but not least, migration tends to engender important financial flux, especially concerning remittances from the migrant to the left-behind. These financial transfers, as they constitute a substantial income for households in the origin country, present great impacts on poverty rates, consumption levels, education, and more generally on the level of development. Indeed, for many developing countries, and especially for Senegal, remittances represent higher financial inflows than foreign direct investments (FDI).

On the destination country's side, the challenge relies on absorbing the migrant inflow in the economy, particularly on the job and housing markets, and to integrate them in the society more globally.

Figure 11: Entire impact chain for Senegal



1.2.2 Transition between impact chains

The transition between the two ICs relies on important assumptions. Indeed, the Global Risk Score obtained as a result of the first IC has no intrinsic value but gets signification only when its variation through time and scenarios is interpreted.

The second impact chain, however, does not directly present any climatic hazard, but rather the anthropological hazard of migration, which constitutes the compounding hazard of the first IC. As developed in the introduction, we assume that the environmental degradation in the origin country is one of the sources of emigration.

The second IC, however, does not especially focus on Senegalese immigrants, but on the global migrant inflow in the City of Paris.

1.2.3 From migrant inflow to integration in the City of Paris

- **Exposure**

In our case study, Paris would be exposed to the migrant flow and particularly the supply they would constitute on the labour market and the demand they would constitute for the housing market. The City is also exposed in terms of social tensions and political instability. Finally, the nature of exposure can be the health system, particularly during the Covid period, with an increased sanitarian threat and the risk of not having the sufficient infrastructures to handle it.

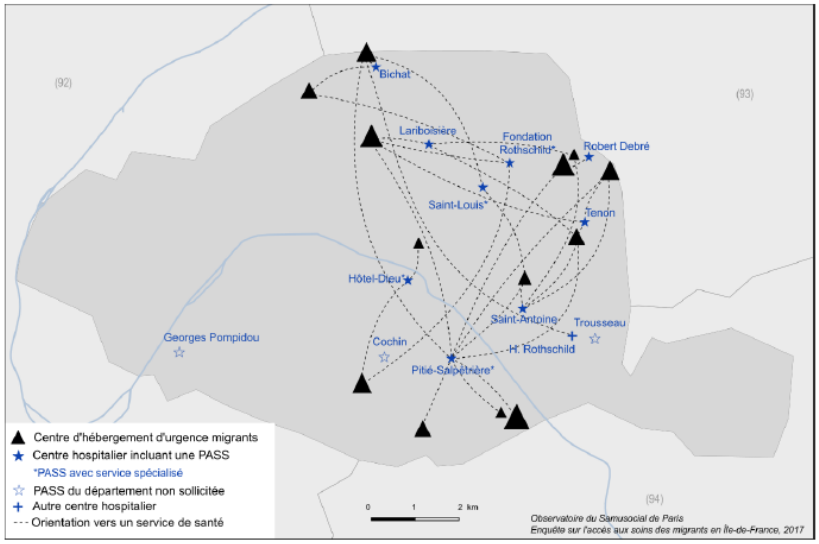
Besides, the level of exposure depends on the size of the migrant inflow as well as its composition. Indeed, the challenges related to migrants' integration may depend on gender, education level, and country of origin. The means required for their welcome also depends on the duration of their stay. Furthermore, migrants willing to leave for another destination, considering Paris as a transitional city, would require only temporary housing and help. However, if they are willing to stay in Paris, the city needs to implement the required devices for their multidimensional integration.

➢ Vulnerability

○ *Sensitivity*

As mentioned before, one of the main sensitivities of Paris will be the initial condition of the housing and labor markets, before the migrant inflow. If these markets are already saturated (unemployment and housing shortage), finding places for the newcomers may be more difficult. The emerging social tensions may be used and manipulated for political aims, which may be dangerous if the initial situation is already fragile. Concerning the health system, the scarcity of infrastructures may be a sensitivity if the needs are superior to the supply. The map below particularly shows the linking program between housing centers and the health system.

Carte 1.2. Les relations des centres d'hébergement parisiens avec les services hospitaliers

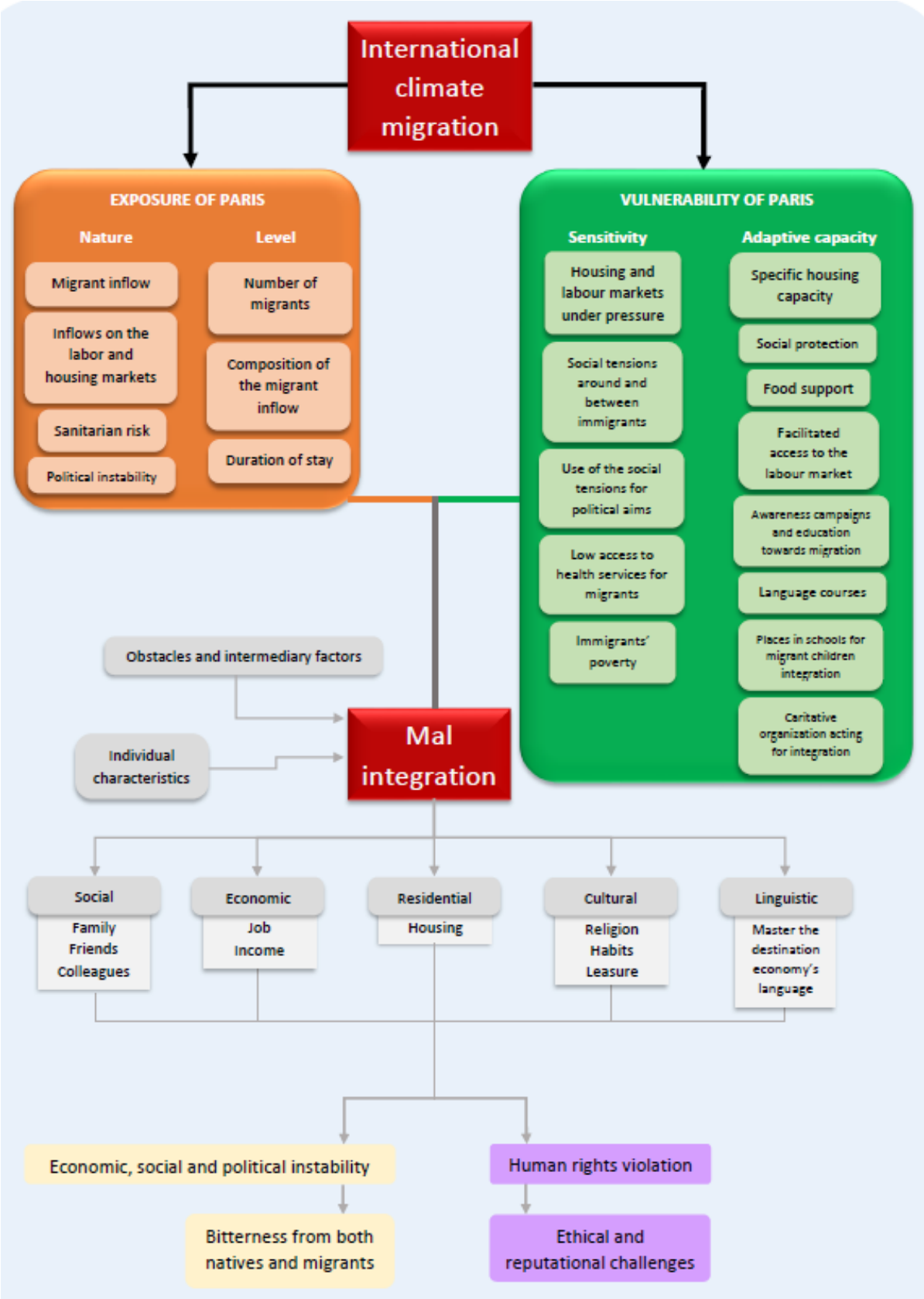


Paris also chose to implement the PASS (permanence of access to health services), to insure that every health need is completed.

○ *Adaptive capacity*

To offset the sensitivities underlined before, the city may have implemented specific housing capacities as well as diverse helping program for migrants and natives (food, language, sensitization, education, access to the labor market). Whereas some programs are ensured by the state or the City, many of them are actually handled by caritative organizations and civil mobilization.


VULNERABILITY OF PARIS
Sensitivity
Housing and labour markets under pressure
Social tensions around and between immigrants
Use of the social tensions for political aims
Low access to health services for migrants
Immigrants' poverty
Adaptive capacity
Specific housing capacity
Social protection
Food support
Facilitated access to the labour market
Awareness campaigns and education towards migration
Language courses
Places in schools for migrant children integration
Caritative organization acting for integration


International climate migration
EXPOSURE OF PARIS
Nature
Level
Migrant inflow
Number of migrants
Inflows on the labor and housing markets
Composition of the migrant inflow
Sanitarian risk
Duration of stay
Political instability
VULNERABILITY OF PARIS
Sensitivity
Adaptive capacity
Housing and labour markets under pressure
Specific housing capacity
Social protection
Social tensions around and between immigrants
Food support
Facilitated access to the labour market
Use of the social tensions for political aims
Awareness campaigns and education towards migration
Low access to health services for migrants
Language courses
Immigrants' poverty
Places in schools for migrant children integration
Caritative organization acting for integration
Obstacles and intermediary factors
Individual characteristics
Mal integration
Social
Family
Friends
Colleagues
Economic
Job
Income
Residential
Housing
Cultural
Religion
Habits
Leasure
Linguistic
Master the destination economy's language
Economic, social and political instability
Human rights violation
Bitterness from both natives and migrants
Ethical and reputational challenges

1.3 Identifying and selecting indicators

Box 3: Research questions and innovations adressed in Module 3

- **RQ1: How to identify the relevant (social-ecological) system elements and their interrelations when doing impact chain assessment?**
  - RQ 1.2: How to identify and consider interdependencies between climate change risks?
- **RQ2: How to better integrate quantitative, semi-quantitative, qualitative and narrative approaches?**
- **RQ4: How to address limitations in the availability of reliable data?**
- **RQ5: How to forward the impact chain approach from a 'linear' representation of risk components towards more system dynamics-oriented models?**

Main Innovation: Co-production of knowledge

The selection of indicators is highly limited by data availability and the relevance of the corresponding indicator. Indeed, the purpose of using indicators is to track the context in a maximum of its dimensions, while keeping clarity and relevance.

In our impact chain approach, we successively select the desired indicators for the Senegalese (1.3.1) and Parisian (1.3.2) contexts, heavily relying on the preparation of vulnerability assessment (Sections 1.1.2 and 1.1.3) as well as impact chains construction (Sections 1.2.1 and 1.2.3).

1.3.1 Indicators for Senegal

1.3.1.1 Hazard

In order to capture the dynamics of climate change (RQ5), the present approach selects indicators for the baseline, established as a mean from 1991 to 2005, and tries to proxy the variation of the corresponding indicators with a time horizon set to 2050, established as a mean between 2040 and 2060.

Regarding the climate change-related threats, temperature, floods and droughts appear as the most significative ones and as the best measured. Moreover, they are the three components for which the projections are the most developed and hence the most accurate. Indeed, the increase in the frequency of cyclones seems relatively very badly approached in the projections. Consequently, we choose not to consider this component of hazard, as well as the water salinization caused by sea-level rise, which will be replaced by narratives (RQ2).

Table 2: Indicators for hazard in Senegal

Component	Indicator used for the baseline	Indicator used for the projections
Temperature increase	Extreme heat	Change in temperature
Rise in sea-levels	Coastal floods	Change in amount of rainfall on very wet days
Floods	Urban floods	
	River floods	
Water stress	Agricultural water risk -quantity	Change in drought
	Agricultural water risk -quality	

As the indicators used for the baseline do not present projections, and in order to address the limitations in the availability of reliable data (RQ4), we select corresponding proxies. Hence, the temperature increase, first approached by an indicator of the intensity and length of extreme heat, is projected using data on temperature increase. Besides, the different types of floods are proxied by the change in amount of rainfall on very wet days. The role of this last indicator is to account for the seasonality disruption induced by climate change. Indeed, even if the global effect of climate change is a reduction in rainfall for Senegal, what really matters is the distribution of these precipitations across the year. In the context of climate change for South countries, seasons are becoming more and more extreme, with dry season becoming hotter and dryer, and rain season becoming wetter. The concentration of the precipitations on certain months engenders important floods.

Finally, dry season and the water scarcity resulting from it is accounted for the baseline by an indicator of agricultural water risk, elaborated concerning its quantity and quality. As projections are very delicate, we approach the evolution of water scarcity using the mean drought index, which accounts for the excess of water present in the soil. We thus lose the “quality” dimension of water.

Whereas using the best measured indicators for the establishment of the baseline enables us to drastically limit uncertainty, we rise awareness on the consequences of using proxies for projections, as their definition and measurement may be sources of errors.

1.3.1.2 Exposure

Our approach to exposure diverges from the usual approach of impact chains. Indeed, we consider here exposure more as aggravating consequences, accounting for both nature and level of exposure. Moreover, in order to keep as much precision as possible and to respect the identified interrelations between social and ecological systems (RQ1), we work on groups of linked hazard and aggravating consequences. Hence, floods are associated with and indicator of the population living on submersible lands, as they would be the most vulnerable.

Parallelly, extreme heat, which is heavily felt in urban areas, is associated with an indicator of urban concentration.

Finally, the exposure to water risk socially and economically depends on the water dependency ratio.

Table 3: Indicators for exposure in Senegal

Components of hazard	Components of exposure (aggravating consequences)
Temperature	Urban concentration
Floods	Population living on submersible lands
Droughts	Water dependency ratio

We choose not to account for the specific agricultural lands that could be flooded or degraded by heat and droughts.

1.3.1.3 Vulnerability

Among the panel of available indicators for sensitivity and adaptive capacity, we select the one that we find the most relevant and for which corresponding data is available. For both categories, we are still constrained to set aside the components for which no indicator is available or considered relevant.

- **Sensitivity**

Table 4: Indicators for sensitivity in Senegal

Sensitivity	Corresponding indicator
Poverty	Population living under $3.20/day, purchasing power parity, constant 2011 dollar
Food insecurity	Prevalence of food insecurity on total population
Dependency to food imports	Indicator of food import dependency
Dependency of the national economy on agriculture	Share of agricultural VA in GDP
Volatility of agricultural production	Standard deviation of production growth rates
Rural population	Rural population share

➢ Adaptive capacity

The adaptive capacity of Senegal mostly consists in the improvement of the agricultural sector's resilience. In this end climate-smart villages are implemented (2 in Senegal), with the goal of common goods' collective management. The goal being two-fold: retaining the young populations in their villages of origin or near them, and thinking collectively about the orientation and desires of the village.

Many other programmes are implemented by the Minister of Environment, giving the priority to adaptation. Indeed, as familial agriculture is dominant in the country and does not pollute much, mitigation does not appear as a main challenge for Senegal.

Table 5: Indicators for adaptive capacity in Senegal

Adaptive capacity	Corresponding indicator
Political stability	Political Stability / No violence (2012-2019)
Political commitment to adaptation	Composite indicator including (early warning measures/climate-smart agriculture), (commitment to managing exposure), (national agricultural adaptation policy), (disaster risk management)
Social protection	Composite indicator including presence, funding, coverage, operation of food programs
Research and education on resilient agricultural methods	Composite indicator including (public expenditure on agricultural research and development) and (access to agricultural technology, education and resources)
Agricultural infrastructures	Composite indicator including (crop storage facilities), (air, port and rail infrastructure), (irrigation infrastructure)
Access to climate and finance-related technologies	Composite indicator access to financial products for farmers, diversification of products, access to market data and mobile banking

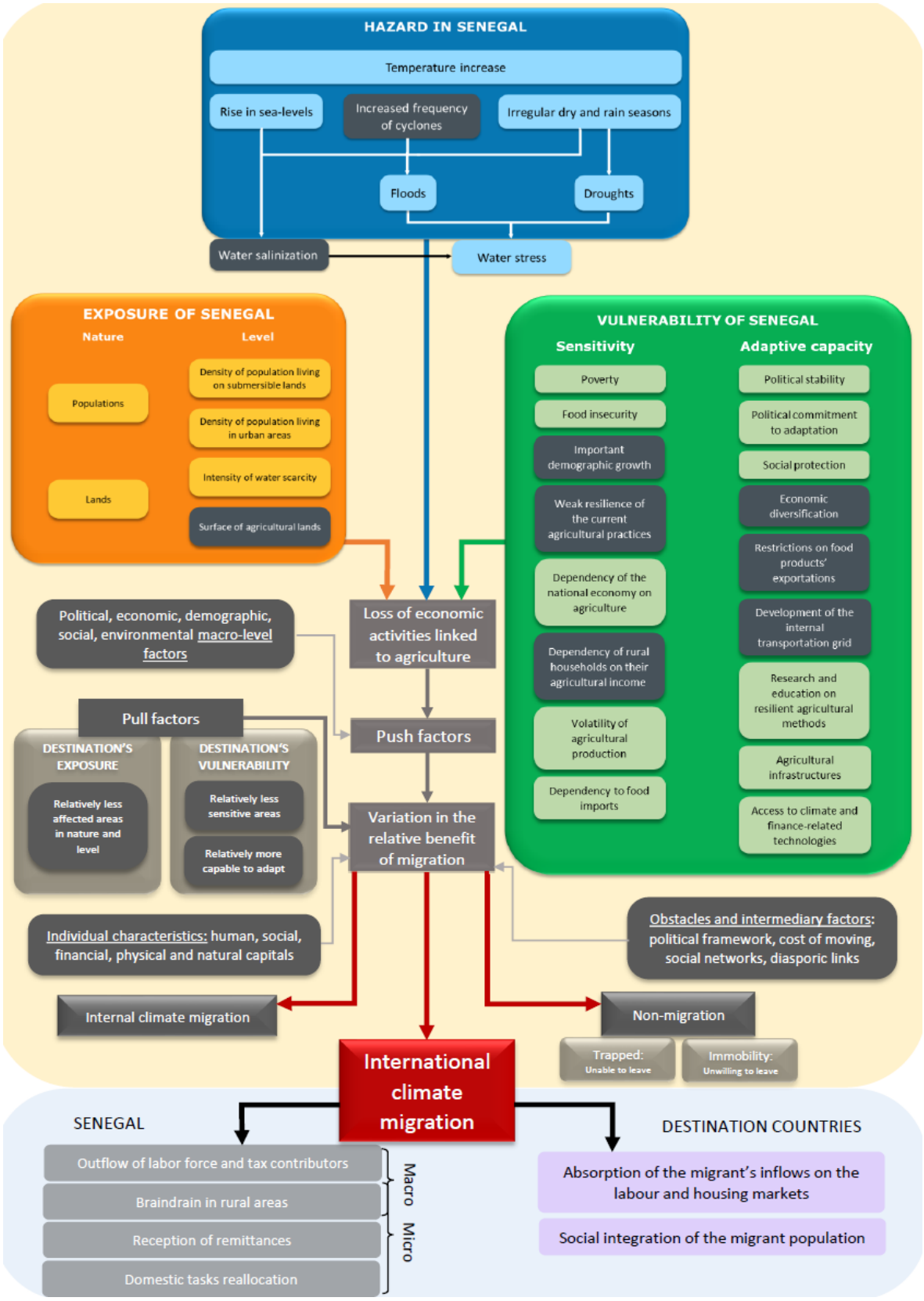
1.3.1.4 Other components

As mentioned in Section 1.2.1, many factors else than hazard, exposure and vulnerability enter in the decision process of migration. In order to simplify the reflexion, we do not consider the environmental pull factors related to the destination economy, and assume that they are constant through time. Similarly, as individual characteristics are impossible to approach without field survey, and as microeconomic reactions are very diverse, we prefer not considering these components rather than badly approach them. Hence, whereas the relevant macro-level factors are included in the 3 main components of our impact chain, the socioeconomic pull factors are bequeathed to the second impact chain.

Besides, the alternatives to international migration, which are internal migration and non-migration, will not be considered here, as the focus is set on international migration. In addition, the consequences of migration will be analysed for the destination economy only, with no specific analysis for the origin country.

Figure 12 presents in grey the components of the impact chain that are ousted for the rest of the work.

Figure 12: Impact chain for Senegal, with considered components



1.3.2 Indicators for Paris

1.3.2.1 Hazard

The term of hazard must here be handled with great awareness. Indeed, hazard tend to refer to negative events that are likely to increase risk, in occurrence, extend or intensity. In our second impact chain, the term of hazard refers to the migration inflow from Senegal. It is essential to highlight that migration can represent both a threat and an opportunity. Indeed, whereas migration waves can destabilize economies in the short term, causing integration problems and markets' saturation, they also represent a great opportunity for cultural diversification and labour supply.

Our indicator for this hazard is constituted by the result of the previous IC, which calculated the propensity to leave from Senegal regarding its main situation, with a specific focus on climate conditions.

Using this indicator as hazard for Paris implies assuming that the risk induced by emigration from Senegal towards all destinations and towards only Paris are the same. This could be interpreted in term of **proportional size of the flow** compared to the entire world and the City of Paris as well as its **relative composition** (same profiles distributed across destination countries).

1.3.2.2 Exposure

In terms of exposure, the definition we give here corresponds to the factors of attraction or resistance for migration inflows. The first indicator we chose to rely on is the diaspora, as it is one of the main attraction factors for newcomers. This importance of diaspora is justified by networks effect and family gathering. The corresponding indicator is the 2017 bilateral migrant stock of Senegalese in France, as it represents the network capable to exerce a potential influence on the left-behind. As precised, the scale taken for the destination is here the entire country of France, and not only the City of Paris. The reliance of this scale change depends on the assumption of identical proportional distribution of Senegalese migrants between the whole country and Paris only.

The second aspect used to assess Paris' exposure to migration is its migration policy. In this purpose, we use the MIPEX (Migrant Integration Policy Index) indicator, which measures the policies to integrate migrants. We could expect that migrants tend to take the direction of countries where their integration is more likely to succeed. Once more, the measures for the corresponding indicator are calculated at the national scale. The use of this indicator hence implies to assume that the quality and quantity of the parisian integration policies is proportional equal to the french ones.

Finally, one of the main factor of attraction determining the choice of the destination corresponds to the relative GDP per capita of the destination, even if its perception tends to be biased by the diaspora. To account for this element of exposure, we use the difference in GDP per capita between Senegal and France.

Table 6: Indicators for exposure in Paris

Components of exposure	Corresponding indicators
Diaspora	2017 bilateral migrant stock of Senegalese in France.
Migration policy	MIPEX (France)
Income difference	Difference in GDP per capita (France-Senegal)

1.3.2.3 Vulnerability

- **Sensitivity**

The sensitivity of the City of Paris is constituted by the difficulties that the city already faces in absence of new migration waves.

Table 7: Indicators for sensitivity in Paris

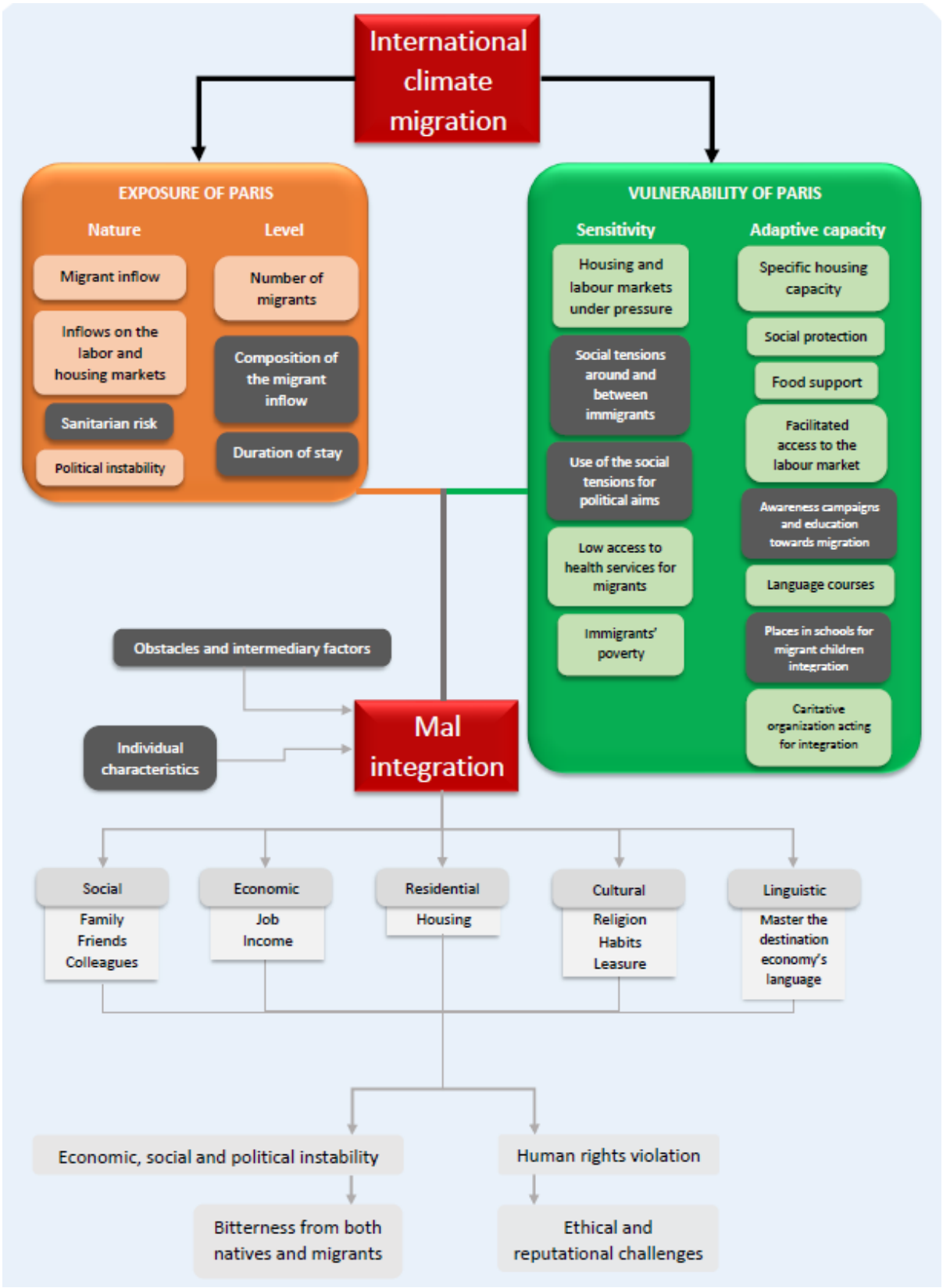
Sensitivity	Corresponding indicator
Poverty	Poverty rate (Paris)
Labor market saturation	Unemployment rate (Paris)
Housing market saturation	Occupation level (Paris)
Health system fragility	Health system fragility (Paris)

- **Adaptive capacity**

Table 8: Indicators for adaptive capacity Paris

Adaptive capacity	Corresponding indicator
Specific housing capacity	Binary for the existence of programs (Paris)
Social protection	Number of beneficiaries of the center for social action in the City of Paris (CASVP)
Food support	Binary for the existence of food programs (Paris)
Facilitated access to the labour market	Binary for the existence of employment programs (Paris)
Language courses	Binary for the existence of language learning programs (Paris)
Caritative organization acting for integration	Number of registered NGO/caritative organizations (Paris)
Political stability	Political Stability / No violence (France)

Figure 13: Impact chain for Paris, with considered components



1.4 Data acquisition and management

Box 4: Research questions and innovations adressed in Module 4

- **RQ1: How to identify the relevant (social-ecological) system elements and their interrelations when doing impact chain assessment?**
  - RQ 1.2: How to identify and consider interdependencies between climate change risks?
- **RQ3: How to integrate in the impact chain framework knowledge from other approaches already existing in literature on the normalization and aggregation phases and the definition of critical thresholds?**
  - RQ 3.1: How to make assessments and results comparable?
- **RQ4: How to address limitations in the availability of reliable data?**
- **RQ5: How to forward the impact chain approach from a 'linear' representation of risk components towards more system dynamics-oriented models?**

Main Innovations: Co-production of knowledge and Exploration of uncertainty dispersion

1.4.1 Data for Senegal

The table below reports the different indicators used, their relative data source and value, and the associated scale.

Table 9: Indicators, data sources and values for Senegal

	Indicators	Data source	Value of the indicator	Scale
Hazard	Extreme heat	ThinkHazard!	3,16	0-4
	Coastal floods	ThinkHazard!	2,62	0-4
	Urban floods	ThinkHazard!	1,42	0-4
	River floods	ThinkHazard!	3,70	0-4
	Agricultural water risk -quantity	WRI Aqueduct	4	0-5
	Agricultural water risk -quality	WRI Aqueduct	5	0-5
Exposure	Urban concentration	ND-GAIN	0,578	0-1
	Population living on submersible lands	ND-GAIN	0,431	0-1
	Water dependency ratio	ND-GAIN	0,338	0-1
Sensitivity	Population living under $3.20/day, PPP, constant 2011 dollar	World Development Indicators	67,5	%
	Prevalence of food insecurity on total population	FAO	49	%
	Indicator of food import dependency	ND-GAIN	0,333	0-1
	Share of agricultural VA in GDP	Senegalese government	17,5	%
	Standard deviation of production growth rates	FAO	0,260	-
	Rural population share	ND-GAIN	0,569	0-1
Adaptive capacity	Political stability / No violence	WGI	-0,099	[-2,5; 2,5]
	Composite indicator including (early warning measures/climate-smart agriculture), (commitment to managing exposure), (national agricultural adaptation policy), (disaster risk management)	GFSI - EIU	19,2	0-100
	Composite indicator including presence, funding, coverage, operation of food programs	GFSI - EIU	47,2	0-100
	Composite indicator including (public expenditure on agricultural research and development) and (access to agricultural technology, education and resources)	GFSI - EIU	8,6	0-100
	Composite indicator including (crop storage facilities), (air, port and rail infrastructure), (irrigation infrastructure)	GFSI - EIU	62,1	0-100
	Composite indicator access to financial products for farmers, diversification of products, access to market data and mobile banking	GFSI - EIU	47,5	0-100

The goal of the analysis being to project the evolution of the situation, we use the forecast data concerning climate to realize different scenarios. We rely on the scenarios previously elaborated by the IPCC, respectively 2.6 and 8.5, for the low and high emissions scenarios, as well as the for the median scenario. Each value given corresponds to the median value of the projections simulated by different models.

Table 10: Projections data

Projections	Data source	Scenario	Variation
Change in temperature	CCKP	2.6	+3,756%
		4.5	+5,130%
		8.5	+6,791%
Change in amount of rainfall on wet days	CCKP	2.6	+2,98%
		4.5	+0,21%
		8.5	+1,21%
Change in drought	CCKP	2.6	+6,277%
		4.5	+12,975%
		8.5	+16,862%

1.4.2 Data for Paris

The table below reports the different indicators used, their relative data source and value, and the associated scale.

Table 11: Indicators, data sources and values for Paris

	Indicators	Data source	Value of the indicator	Scale
Hazard	Global Risk Score	First IC	-	0-1
Exposure	2017 bilateral migrant stock	World Bank Bilateral Migration Database	119 661	-
	Integration policies	MIPEX	56	0-100
	Difference in GDP per capita (PPP, 2017 constant US$, 1991-2005 mean)	WDI	35 036	-
Sensitivity	Poverty rate (Paris)	INSEE	16,1	%
	Unemployment rate (Paris)	INSEE	10	%
	Occupation level (Paris)	INSEE	91,9	%
	Health system fragility (Paris)	SAMU social	13	-
Adaptive capacity	Binary for the existence of programs (Paris)	Divers	1	0-1
	Number of beneficiaries of the centre for social action in the City of Paris (CASVP)	CASVP	215 291	-
	Binary for the existence of food programs (Paris)	Divers	1	0-1
	Binary for the existence of employment programs (Paris)	Divers	1	0-1
	Binary for the existence of language learning programs (Paris)	Divers	1	0-1
	Number of registered NGO/caritative organizations (Paris)	Divers	1	0-1
	Political Stability / No violence (France)	WGI	0,24	[-2,5; 2,5]

1.5 Normalizing indicators

Box 5: Research questions and innovation adressed in Module 5

- **RQ1: How to identify the relevant (social-ecological) system elements and their interrelations when doing impact chain assessment?**
  - RQ 1.2: How to identify and consider interdependencies between climate change risks?
  - RQ 1.6: How to identify potentially beneficial vs. potentially problematic interdependencies?
- **RQ3: How to integrate in the impact chain framework knowledge from other approaches already existing in literature on the normalization and aggregation phases and the definition of critical thresholds?**
  - RQ 3.1: How to make assessments and results comparable?
- **RQ5: How to forward the impact chain approach from a 'linear' representation of risk components towards more system dynamics-oriented models?**

1.5.1 No need of normalization

Among the indicators used in our IC, some were already normalized and did not need further manipulation for this module. It is especially the case for the following indicators:

Table 12: Already normalized indicators

Indicators normalized for Senegal	Indicators for Paris
• ThinkHazard! indicators are normalized on a 0-4 scale • WRI Aqueduct indicators are normalized on a 0-5 scale • ND-GAIN indicators are already normalized on a 0-1 scale • GFSI – EIU indicators are normalized to 0-100 scale • WGI indicators are normalized on a [-2,5; 2,5] interval	• The score from the previous IC, used for hazard, is already normalized to 1 • MIPEX indicator is normalized on a 0-100 scale • The occupation level (housing market) measured by INSEE is relevant when expressed on a 0-100 scale • The arbitrary binary variables are, by definition, expressed on a 0-1 scale • WGI indicators are normalized on a [-2,5; 2,5] interval

1.5.2 Normalization by expert's judgment and/or literature

Some indicators judged as relevant rely on unnormalized data, as percentages. It is the case concerning the poverty, food insecurity, as well as agricultural dependence indices for Senegal.

In order to normalize them, we use already defined categories and experts' wisdom. Hence, the indicators' values are modified as follow:

Table 13: Normalization by expert's judgment and/or literature

Country	Indicator	Initial value	Final value	Justification
Senegal	% of population living under $3.20/day 2011 PPP	67,5%	0,67	https://atlasocio.com/cartes/economie/pauvrete/carte-monde-taux-de-pauvrete-en-2018_atlasocio.png
	Food insecurity prevalence	49%	0,8	https://fr.wikipedia.org/wiki/Liste_des_pays_par_taux_de_malnutrition
	Agricultural Value Added	17,5%	0,7	Expert judgment
Paris	2017 bilateral migrant stock	119 661	1	Expert judgment (France is the first Northern country in terms of Senegalese migrants stock)
	Difference in GDP per capita (PPP, 2017 constant US$, 1991-2005 mean)	35 036	0,9	Expert judgment
	Poverty rate (Paris)	16,1%	0,167	https://atlasocio.com/cartes/economie/pauvrete/carte-monde-taux-de-pauvrete-en-2018_atlasocio.png
	Number of health infrastructures available linked to migrants welcoming centres	13	0,2	Expert judgment

1.5.3 Time-series min/max normalization

In the case of Senegal, one of the indicators is normalized using a time-series min/max normalization. Indeed, the indicator accounting for the volatility of agricultural production through the standard deviation of production growth rates, coming from the Food and Agriculture Organization (FAO), has been normalised using this method. We estimate the min-max interval on the period 2012-2020, which rises to 0,167. The normalized indicator hence corresponds to the difference between its value and the minimum value of the interval, divided by the interval's range.

$$Normalized\ volatility\ = \frac{(Indicator\ value\ in\ 2020)\ -\ (min\ on\ the\ 2012-2020\ period)}{(max\ on\ the\ 2012-2020\ period)\ -\ (min\ on\ the\ 2012-2020\ period)}$$

$$\frac{0{,}26\ -\ 0{,}189}{0{,}356\ -\ 0{,}189} = 0{,}425$$

Normalized to 1, our volatility indicator rises to 0,425.

In the case of Paris, two indicators are normalised using time-series min/max: unemployment rate (INSEE), accounting for the labor market saturation, and the number of CASVP beneficiaries (CASVP), accounting social protection's quality. Table 14 reports the results following the former equation.

Table 14: Time-series min/max normalization

Indicator	Initial value	Time-serie min (on the 1982-2021 period)	Time-serie max (on the 1982-2021 period)	Normalized score
Unemployment rate	10%	5,5%	10,2%	0,96
Number of beneficiaries from CASVP	215 291	165 518	278 380	0,44

1.6 Weighting

Box 6: Research questions and innovations adressed in Module 6

- **RQ1: How to identify the relevant (social-ecological) system elements and their interrelations when doing impact chain assessment?**
  - RQ 1.2: How to identify and consider interdependencies between climate change risks?
  - RQ 1.6: How to identify potentially beneficial vs. potentially problematic interdependencies?
- **RQ 2: How to better integrate quantitative, semi-quantitative, qualitative and narrative approaches?**
- **RQ3: How to integrate in the impact chain framework knowledge from other approaches already existing in literature on the normalization and aggregation phases and the definition of critical thresholds?**
  - RQ 3.1: How to make assessments and results comparable?
- **RQ5: How to forward the impact chain approach from a 'linear' representation of risk components towards more system dynamics-oriented models?**

Main Innovation: Test of new methodological approaches

Risk assessment requires to allocate weights to its different components before aggregation. This weighting occurs twice in our process. First, we must define weights among the indicators of each component. Second, we must allocate a specific weight to the components for the aggregation resulting in the risk score.

1.6.1 Intra-components weighting

Our analysis relies on **equal weighting**. Hence, into each component of risk, indicators are allocated with the same importance, either for Senegal or Paris. However, the procedures allowing to apply these equal weights differ among the ICs.

Indeed, in the case of Senegal's hazard, the identical weights are allocated to categories of indicators rather than indicators themselves, in order to gain relevance (cf. Figure 14). Similarly, in the case of vulnerability, indicators are first gathered by categories (sensitivity and adaptive capacity) using equal weights, and then aggregated with equal importance (cf. Figure 15). As there are no categories for exposure's components, the weighting procedure is made easier (cf. Figure 16).

Figure 14 : Weighting in the aggregation procedure for hazard (Senegal)

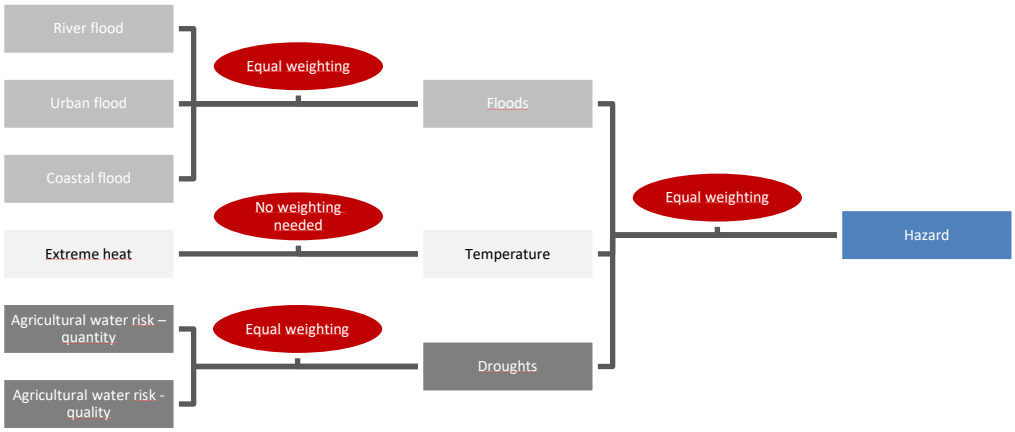


Figure 15: Weighting in the aggregation procedure for exposure (Senegal)

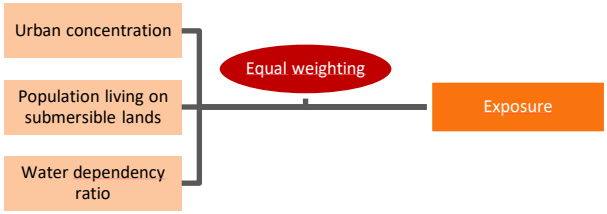
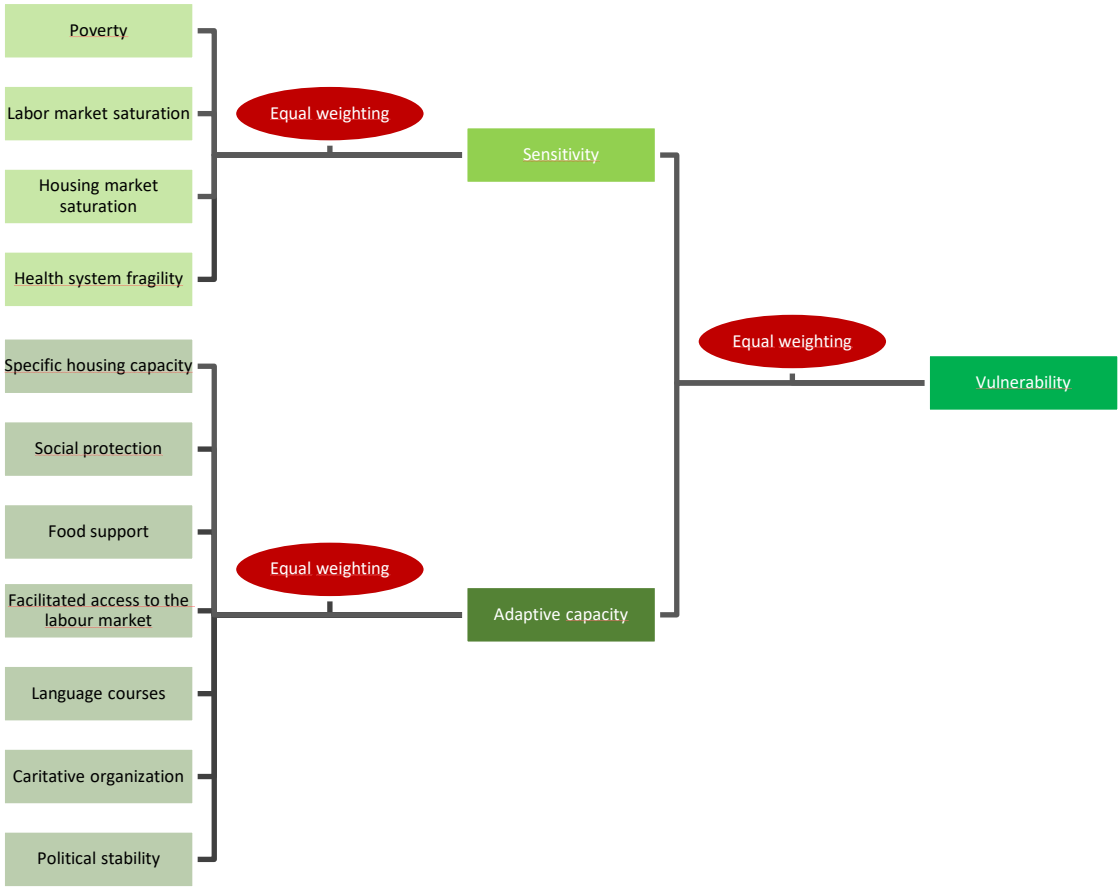


Figure 16: Weighting in the aggregation procedure for vulnerability (Senegal)



Applying equal weights is easier in the Parisian IC. First, as hazard is composed by only one indicator, there is no need to weight it. The application of weights in the case of exposure and vulnerability is similar to the Senegalese procedures (cf Figure 17 and Figure 18).

The choice of this weighting method is justified by its robustness and simplicity both to apply and understand. Moreover, among our multiple indicators and built categories, any of them appeared as obviously more important than the others. This similar importance sustain the choice of this method.

Figure 17: Weighting in the aggregation procedure for exposure (Paris)

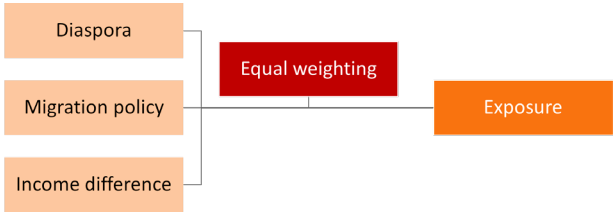


Figure 18: Weighting in the aggregation procedure for vulnerability (Paris)

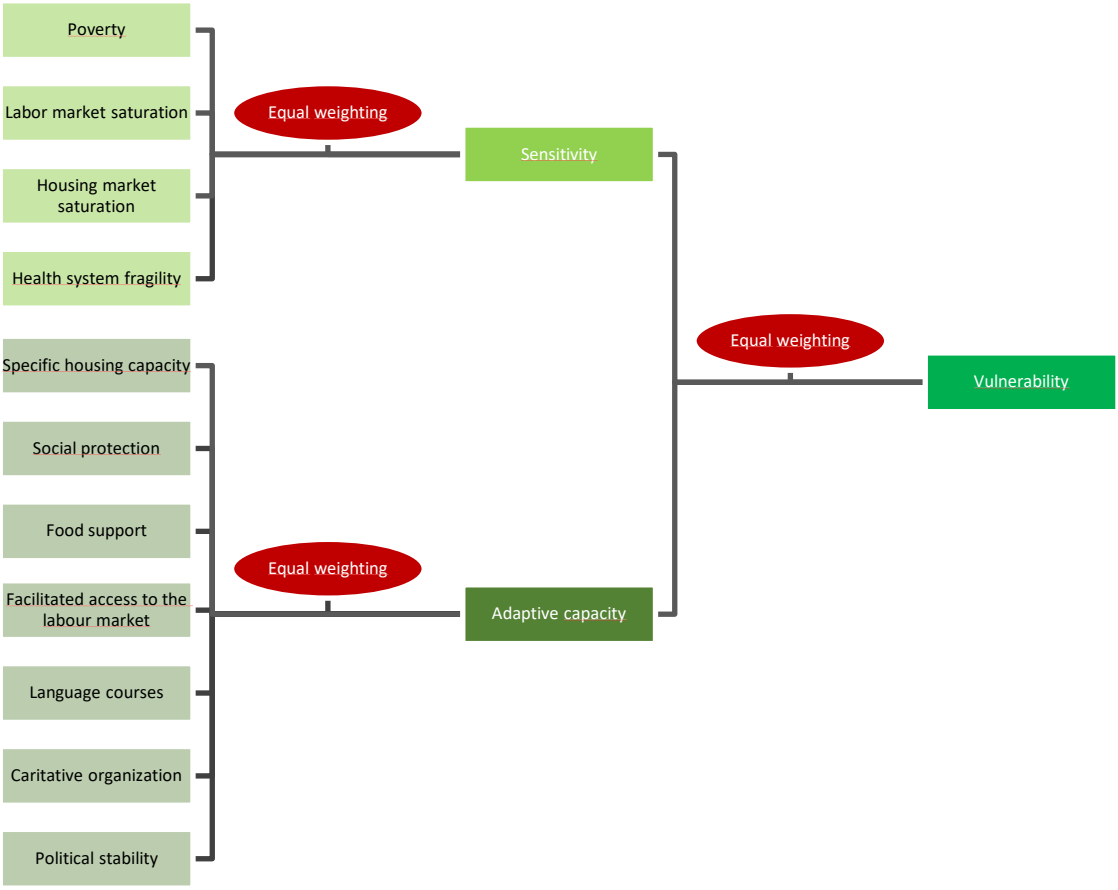


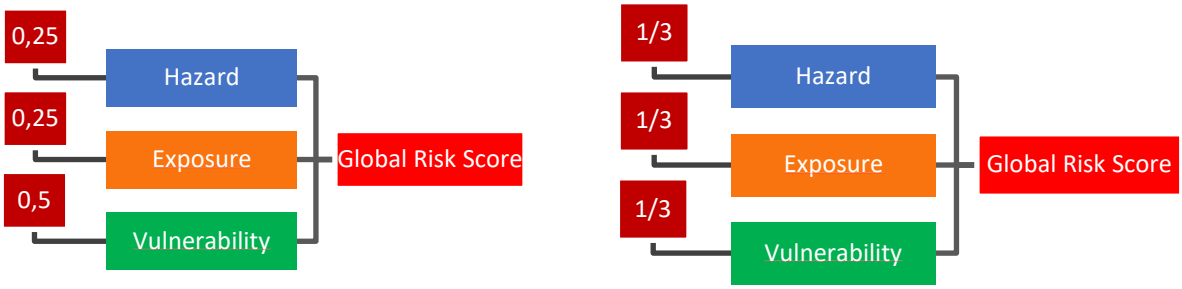
Table 15: Common methods for indicator weighting

Method Name	Type	Examples	Formulas	Benefits	Drawbacks
Equal weighting	Equal weighting	Human Development Index (UNDP, 1990) Genuine Savings (WorldBank, 1999)	$\omega_i = \omega,\ i = 1, \ldots, m,$ where ω_i is the weight of the i^{th} indicator and ω a constant used as the weights for all the indicators	Simple, replicable and straightforward.	No insights into indicator relationships; risk of double weighting.
PCA/FA	Statistic-based	Environmental Sustainability Index (Sands and Podmore 2000) The 2006 European e-Business Readiness Index (Pennoni et al., 2006)	$\omega_i = r_j(l_{ij}^2/E_j)$ $i = 1,\ldots,m;\ j = 1,\ldots,n$ where r_j is the proportion of the explained variance of factor j (or the intermediate composite j) in the data set, l_{ij} the factor loading of the i^{th} indicator on factor j and E_j the variance explained by the factor j	Reduces the risk of double weighting, classifying ungrouped indicators.	Dimensions of sustainability are unpredictable, and weights may differ from reality.
Benefit of the doubt approach (BOD)	Statistic-based	Meta-index of Sustainable Development (Cherchye and Kuosmanen 2004) Macro-economic performance evaluation (Melyn and Moesen 1991)	$\omega_c = \arg\max_{\omega_{c,i}} \frac{\sum_{i=1}^{m} \omega_{c,i} I_{c,i}}{\max_{y_j \in \{\text{studied units}\}} \sum_{i=1}^{m} \omega_{c,i} I_{j,i}}$ $s.t. \sum_{i=1}^{m} \omega_{c,i} I_{j,i} \leq 1,\ \omega_{c,i} \geq 0$ $\forall\ i = 1, \ldots, m;\ \forall\ j = 1, \ldots, n$ where $\boldsymbol{\omega_c}$ is the weight vector of unit c, $\omega_{c,i}$ the weight of the i^{th} indicator of unit c, $I_{c,i}$ the normalized score of the i^{th} indicator of unit c, and $I_{j,i}$ the normalized score of the i^{th} indicator of the j^{th} unit	The processes of weighting, aggregation, and index construction are efficiently integrated. Weights are selected to maximize the index for each unit.	Results may not be comparable and lack transparency. A multiplicity of solutions exists.
Regression analysis (RA)	Statistic-based	National Innovative Capacity (Porter and Stern 2001)	$\omega_i = \beta_i,\ i = 1,\ldots,m$ where β_i is the regression coefficient of the i^{th} indicator	Results can be used for updating or validating weights.	Either multi-collinearity among indicators or an improper dependent variable may lead to poor results.
Unobserved component models (UCM)	Statistic-based	The aggregate governance indicators (Kaufmann et al., 1999)	$\omega_i = \frac{\delta_i^{-2}}{1 + \sum_{i=1}^{m} \delta_i^{-2}}$ $i = 1\ldots,m$ where δ_i is the variance of the i^{th} indicator	The processes of weighting, aggregation, and index construction are efficiently integrated. Statistical significance can be expressed when conducting comparisons.	Results are sensitive to outliers. Problems of identification may occur if indicators are highly correlated. Reliability and robustness of the model may be lost when adequate data are not available.
Budget allocation (BAL)	Public/Expert opinion-based	The Eco-indicator 99 (Goedkoop and Spriensma, 2001) Overall Health System Attainment (Murray et al., 2000)	–	Transparent and explicit.	Measuring urgency instead of importance; region-specific.
Public opinion (PO)	Public/Expert opinion-based	Concern about environmental problems Index (Parker, 1991)	–	Transparent and participatory.	Measuring concern instead of importance; region-specific.
Analytic hierarchy process (AHP)	Public/Expert opinion-based	Composite sustainability performance index (Singh et al., 2007) Index of Environmental Friendliness (Puolamaa et al., 1996)	$A\omega = \lambda\omega$ where A is the comparison matrix, λ the largest eigenvalue of A, and ω the weight vector as well as the eigenvector corresponding to λ.	Has a hierarchical structure that is in line with the structure of sustainability frameworks. Simple and flexible. Providing consistent verification operation. Available for both quantitative and qualitative data.	Requirement of a high number of pairwise comparisons. Inconsistency and cognitive stress may exist if there are too many indicators in each cluster.
Conjoint analysis (CA)	Public/Expert opinion-based	Indicator of quality of life in the city of Istanbul (Ülengin et al., 2001)	$\omega_i = \frac{\partial P(I_1,\ldots,I_m)}{\partial I_i}$ where $P(I_1,\ldots,I_m)$ is the preference function defined by researchers and I_i the i^{th} indicator	Results can be easily used for making sustainability plans. Available for both quantitative and qualitative data.	Requires a large sample of respondents. Has complicated estimation process.

From Gan and al., 2017

1.6.2 Inter-components weighting

Two types of inter-components weighting have been used in order to check the robustness of the results:



1.7 Aggregation

Box 7: Research questions and innovations adressed in Module 7

- **RQ1: How to identify the relevant (social-ecological) system elements and their interrelations when doing impact chain assessment?**
  - RQ 1.2: How to identify and consider interdependencies between climate change risks?
  - RQ 1.4: How to support methods for result evaluation?
  - RQ 1.6: How to identify potentially beneficial vs. potentially problematic interdependencies?
- **RQ 2: How to better integrate quantitative, semi-quantitative, qualitative and narrative approaches?**
- **RQ3: How to integrate in the impact chain framework knowledge from other approaches already existing in literature on the normalization and aggregation phases and the definition of critical thresholds?**
  - RQ 3.1: How to make assessments and results comparable?
- **RQ5: How to forward the impact chain approach from a 'linear' representation of risk components towards more system dynamics-oriented models?**

Main Innovations: Test of new methodological approaches and Exploration of uncertainty dispersion

1.7.1 Aggregation methods

Many methods have been elaborated so far concerning indicators' aggregation (Table 16). In our analysis, we used arithmetic, geometric as well as weighted product methods.

Table 16: Common methods used for indicators' aggregation

Common methods for indicator aggregation (based mainly on Munda and Nardo (2005), Beliakov et al. (2007), OECD (2008), and Pollesch and Dale (2015)).

Common methods for aggregation	Examples	Formulas	Benefits	Drawbacks
Additive aggregation	Environmental Performance Index (Esty et al., 2006) Well Being Index (Prescott-Allen 2001)	$SI = \omega_1 I_1 + \omega_2 I_2 + \ldots + \omega_m I_m = \sum_{i-1}^{m} \omega_i I_i$ where SI is the sustainability index, ω_i the weight of the i^{th} indicator, and I_i the normalized score of the i^{th} indicator.	Transparent and simple. Easy to execute sensitivity analysis and uncertainty quantification.	Rigorous prerequisites exist, such as mutually preferentially independence.
Geometric aggregation	Living Planet Index(Loh et al., 1998; Loh et al., 2005)	$SI = I_1^{\omega_1} I_2^{\omega_2} \ldots I_m^{\omega_m} = \prod_{i=1}^{m} I_i^{\omega_i}$ where SI is the sustainability index, ω_i the weight of the i^{th} indicator, and I_i the normalized score of the i^{th} indicator.	Transparent and simple. Can be used for all kinds of ratio-scale variables.	Rigorous prerequisites exist, such as mutually preferentially independence.
Non-compensatory aggregation methods	Index for "Social Multi-Criteria Evaluation"(Munda 2004)	Rank($Unit_i$) $s.\ t.\ \varphi_* = \max \sum e_{jk}$ $i = 1,\ldots,n$ where Rank ($Unit_i$) is the overall ranking of the n researched units, $\varphi_*$the corresponding score of the final ranking of the researched units, and e_{jk} the generic element of the outranking matrix.	No ad hoc restrictions.	Computational problems may be caused by the increasing number of units or indicators. Losing information on the intensity of sustainability.

For each different method used, we applied it from the beginning to the end of the calculation (from the intra-components aggregation to the inter-components aggregation), in order to preserve relevance.

1.7.1.1 Arithmetic

Arithmetic aggregation stands for the easiest method, applying the corresponding weight to each component and simply aggregating them. It is transparent, simple to apply, and simple to understand. It is widely used among the most famous indicators.

$$Component\ or\ Risk\ score = \sum Wi \times Ii$$

Restricted to the assumption that Ii is normalized to 1 and $\sum Wi = 1$.

1.7.1.2 Weighted product

The weighted product methodology is part of the no compensatory aggregation methodologies, aiming at reducing the potential substitution between components. If a component present an extreme-value score, and if its weight is important, this extreme value will highly be accounted for. In other words, weighted product aims at stressing disparities in order to get a more easily and distinctly classified rank. The corresponding formula is the following:

$$Component\ or\ Risk\ score = \prod Ii^{Wi}$$

Restricted to the assumption that Ii is normalized to 1 and $\sum Wi = 1$.

However, as this method is not that common, and as it is better used in the case of comparisons (which is not the goal of our analysis here), we apply it on the first IC only, and then rely on the two other methods only.

1.7.1.3 Geometric

Another method, that seems to have emerged during the last decade, corresponds to the geometric aggregation method. This method represents a middle road between arithmetic and weighted product aggregation methods. Indeed, it allows for substitutability of the components but sanctions extreme risk way more than the arithmetic aggregation does. As the risk may critically depend on only some components, whatever the level of others is, this method enables to consider the variance of the score as an additional factor of the climate-related risk. As this method gives greater weights to larger values, the resulting scores tend to be higher than with the arithmetic aggregation.

$$Component\ or\ Risk\ score = (\prod Ii)^{1/n}$$

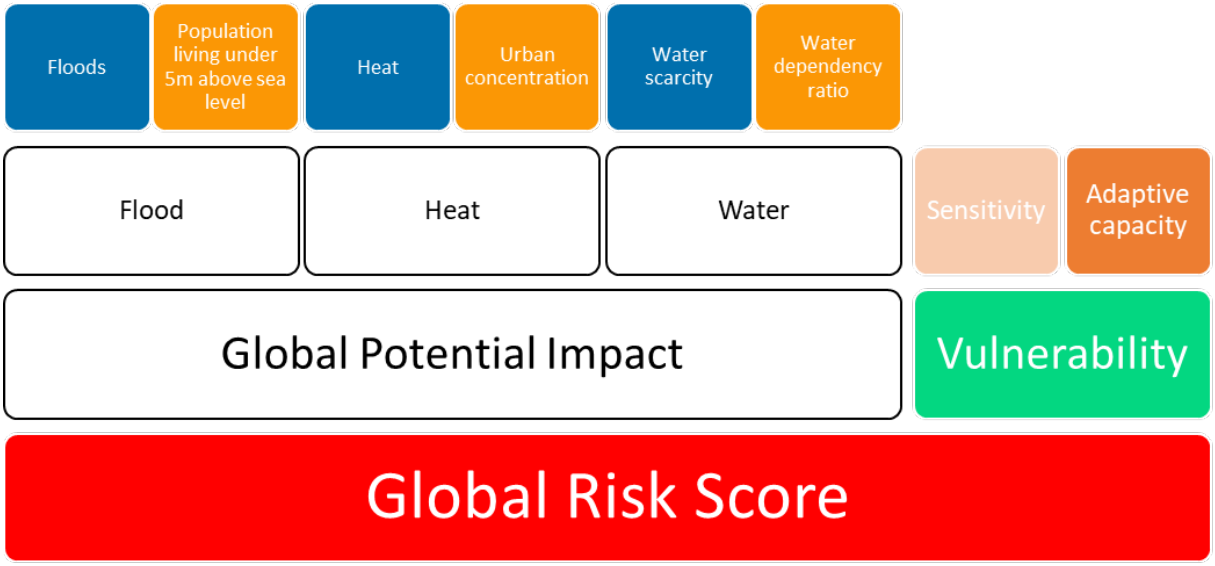
Where n corresponds to the number of normalized components *I* to be aggregated.

1.7.2 Aggregation moments

In the case of our first IC, we face 3 possibilities of aggregation moments. Indeed, the configuration of our indicators allows us to distinguish different methods, leading sometimes to different, other times to identical results. For each moment, only hazard and exposure components are concerned, the method used to get the vulnerability score remaining unchanged.

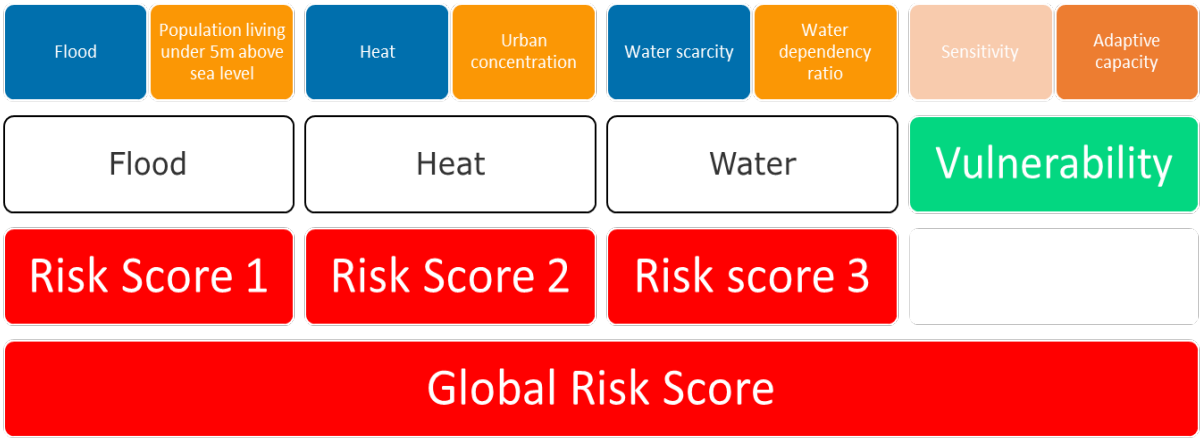
Our first aggregation method consists in coupling each indicator of hazard with its corresponding indicator of exposure, this last one accounting for an "aggravating consequence" of hazard. Using an equal weighting method between the hazard and the exposure indicators, this method enables us to get a score for each couple (flood, heat, water). The aggregation of this sub-indicators of risk gives a first indicator of "global potential impact", which, once coupled with the indicator of vulnerability, results in the 'global risk score".

Figure 19: First aggregation moment



As a difference, the second aggregation methods couples the sub-indicators of potential impact to the indicator of vulnerability, without passing through the step of aggregation into a "global potential impact" as in the first moment. The shade is light but the two moments give different results when using geometric aggregation method. After associating each sub-indicator of potential impact to the same indicator of vulnerability, we obtain 3 sub-indicators of the global risk score, which are aggregated in the final step.

Figure 20: Second aggregation moment



The third aggregation moments is inspired from the usual IC methodology, which first elaborates a distinct score for each component and then proceeds by inter-components aggregation, hence obtaining the global risk score. In our case, we consider that this method does not allow to take into account the particular link identified between our indicators, hence resulting in a loss of accuracy and an increase in uncertainty.

Figure 21: Third aggregation moment

When using the arithmetic aggregation methods, all aggregation moments give the same results. Conversely, the different moments give distinct results when using the geometric method. Finally, the weighted product aggregation method results in identical scores for the two first moments of aggregation and a different score for the third one.

Even if the variation in score is not huge in absolute terms, in remains important in relative terms, and this disparity of results highlights how important the choice of both the method and the moment of aggregation is determining for the final outcome.

Coupling indicators of hazard with their corresponding indicators of exposure stands for an innovation, and could even be deepened with an extension of this link considering vulnerability indicators.

1.8 Presentation of the results

Box 8: Research questions and innovations adressed in Module 8

- **RQ1: How to identify the relevant (social-ecological) system elements and their interrelations when doing impact chain assessment?**
  - RQ 1.2: How to identify and consider interdependencies between climate change risks?
  - RQ 1.4: How to support methods for result evaluation?
  - RQ 1.5: How to combine a multitude of (sector-specific) information and still present them in a clear and concise manner?
  - RQ 1.6: How to identify potentially beneficial vs. potentially problematic interdependencies?
- **RQ 2: How to better integrate quantitative, semi-quantitative, qualitative and narrative approaches?**
- **RQ3: How to integrate in the impact chain framework knowledge from other approaches already existing in literature on the normalization and aggregation phases and the definition of critical thresholds?**
  - RQ 3.1: How to make assessments and results comparable?
- **RQ4: How to address limitations in the availability of reliable data?**
- **RQ5: How to forward the impact chain approach from a 'linear' representation of risk components towards more system dynamics-oriented models?**

Main innovations: Co-production of knowledge and Integration of transboundary risks

The present study not only brings results on the question of international climate migration between Senegal and Paris, but also highlights progress in methodological aspects of the impact chain, concerning weighting and aggregation questions. This section successively presents the methodological and case-study specific results.

It is important to keep in mind that the obtained scores are delicate to interpret as absolute risk indicators for two reasons. First, because it would induce considering emigration as a pure risk, and second because the resulting score depends too much on the sub-indicators used to obtain the components scores, and these indicators may be too arbitrary to ensure reliability.

We then prefer to analyse the variations of risk score across aggregation moments and methods, and across climate scenarios, in order to identify **relative risk.**

1.8.1 Methodological results

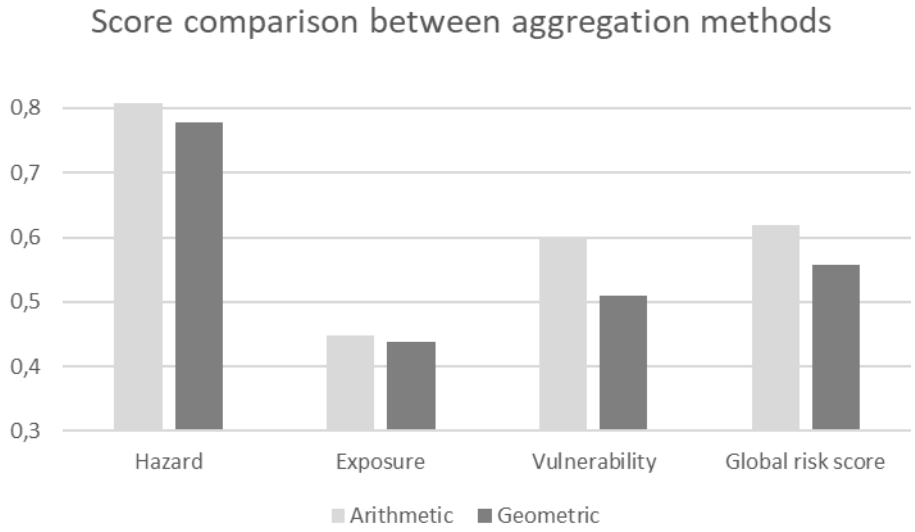
1.8.1.1 Results on the weighting method

The weighting method only imports when analysing the results from the arithmetic aggregation, as the geometric one does not integrate weights. Using the results from the first IC of our case study, we observe in the table below that equal weighting between categories (1/3 for hazard, exposure and vulnerability) raises higher scores than the unequal weighting (0.25 for hazard and exposure and 0.5 for vulnerability) does. This is mostly linked to the fact that Hazard presents the highest scores and allocating more weight to this component hence brings higher risk scores.

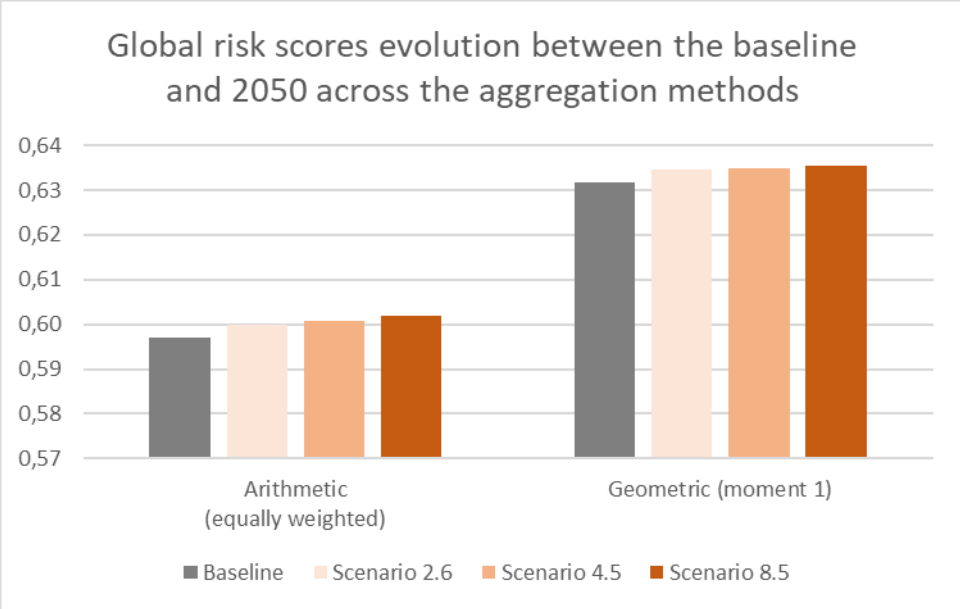
	Arithmetic aggregation					
	Global Risk Score (unequal weighting)			Global Risk Score (equal weighting)		
	Mom1	Mom2	Mom3	Mom1	Mom2	Mom3
Baseline	0,613	0,613	0,613	0,618	0,618	0,618
Scenario 2.6	0,619	0,619	0,619	0,627	0,627	0,627
Scenario 4.5	0,621	0,621	0,621	0,629	0,629	0,629
Scenario 8.5	0,624	0,624	0,624	0,633	0,633	0,633

1.8.1.2 Results on the aggregation method

The two main methods employed here are the arithmetic and geometric aggregations. We notice on the graph below (using the third aggregation method in the first IC), and referring to the table below, that the geometric method always gives lower risk scores, which is counter-intuitive as mentioned in section 1.7.1.3. Knowing that the principle of the geometric method is to sanction the intra-components disparities, the fact that geometric aggregation gives lower results may signify that intra and inter-components categories are quite homogenous in terms of scores.



However, referring to the graph below, presenting the risk scores of the second IC across the different scenarios, using equal weighting and first moment of aggregation (which brings the lowest results for geometric aggregation), we can easily observe that the arithmetic aggregation raises lower results than the geometric one for the final scores. Following the former logic, the boom in geometric scores may be linked to important intra and inter-components disparities.

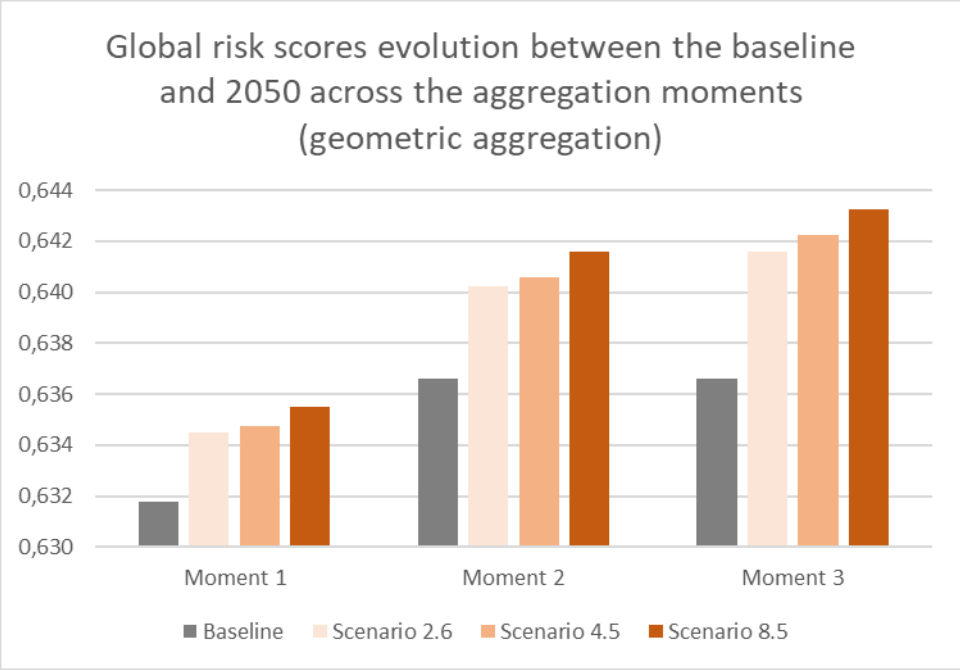


1.8.1.3 Results on the aggregation moment

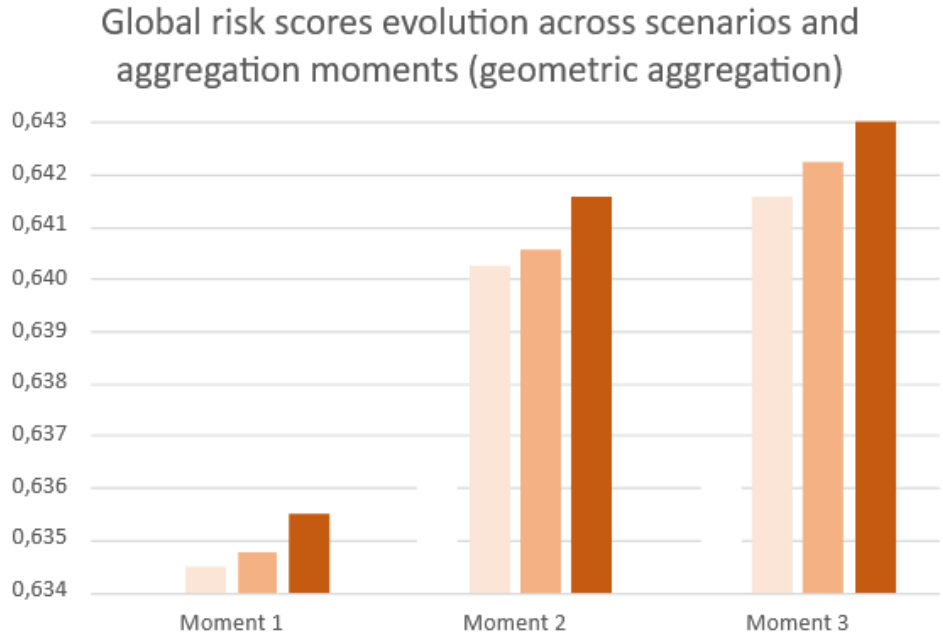
Referring to the former and next table, we observe that the aggregation moment importantly influences the results of the geometric scores, whereas it has no impact on the results obtained by the arithmetic ones. This is once more linked to questions of intra/inter categories disparities.

	Geometric aggregation		
	Global Risk Score (equal weighting)		
	Moment 1	Moment 2	Moment 3
Baseline	0,545	0,558	0,558
Scenario 2.6	0,552	0,567	0,571
Scenario 4.5	0,553	0,568	0,573
Scenario 8.5	0,555	0,571	0,575

This result is constant through ICs, as the second one gives the same result. Knowing that the third moment of aggregation corresponds to the usual method of Impact Chain (as described in the Vulnerability Sourcebook), and noticing that this moment brings the highest results, we may wonder if the risk scores usually obtained by ICs in other contexts are not over-estimated.



We also observe that, no matter the aggregation moment, the shape of the evolution between scenarios is the same. The gap between the baseline and the scenarios' scores is explained by the difference in time (baseline in 2020 and projections in 2050). Hence, even a scenario of low emissions would see a big increase in the risk of badly integrating climate migration in the City of Paris. However, we see a non-negligeable deterioration of the risk score between the emission scenarios, highlighted on the graph below.



1.8.2 Case-study specific results

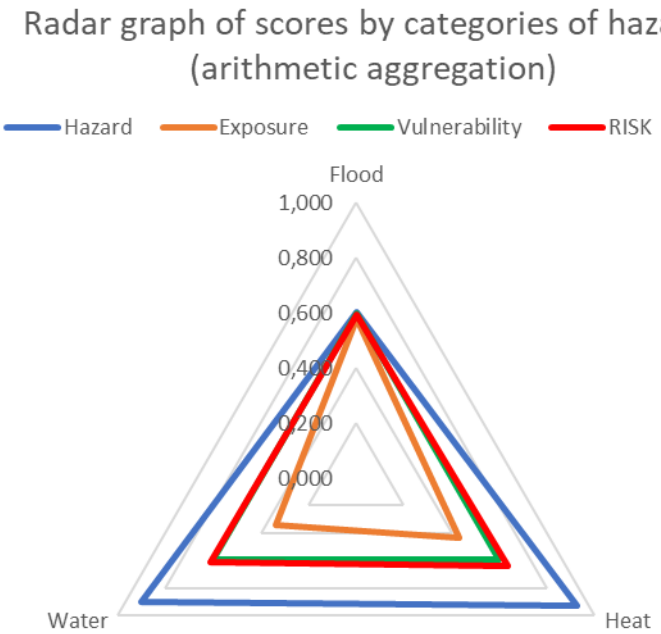
The following section successively reports the results for the Senegalese and Parisian risk scores. The lector must keep in mind that these results rely on the hypothesis that no exogenous and unconsidered event would intervene. Moreover, it assumes a linear relationship between environmental degradation and emigration flows, whereas the decision to emigrate actually gathers many human behaviors and decisions, as well as other unobservable factors.

1.8.2.1 Results for Senegal

1.8.2.1.1 Baseline for Senegal

Senegal presents particularly high hazard scores, especially concerning heat and water. Conversely, the exposure to flood, which corresponds to the population living under 5 meters above sea level, is higher than the score of exposure for heat and water scarcity, respectively urban concentration and water dependency ratio. Finally, the vulnerability score is the same for all categories.

	Flood	Heat	Water	Total
Hazard	0,600	0,924	0,900	0,808
Exposure	0,578	0,431	0,338	0,449
Vulnerability	0,598			0,598
Risk	0,593	0,637	0,608	-



The 2nd moment of aggregation gives multiples scores for intermediary risk. This radar plot helps identifying the hazards that are the most likely to impact the global risk score. Hence, it seems that all scores are close, but heat appears as the leading factor of emigration.

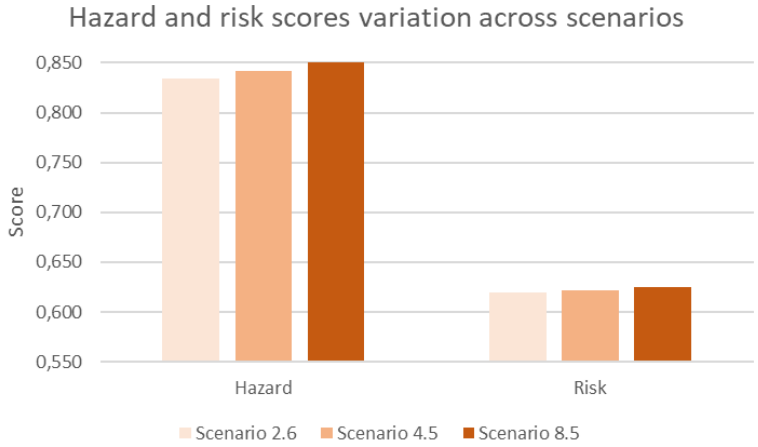
	Arithmetic	Geometric
Hazard	0,808	0,777
Exposure	0,449	0,438
Vulnerability	0,598	0,509
Global risk score	0,618	0,558

Despite arithmetic aggregation draws higher results than the geometric one, the relative variation is still equivalent.

1.8.2.1.2 Projections for Senegal

The variation of the hazard score through the different scenarios engenders the variation of the risk score, but in lower proportions as this last one is mitigated by the stability of exposure and vulnerability.

	Scenario 2.6	Scenario 4.5	Scenario 8.5
Hazard	0,834	0,841	0,854
Risk	0,619	0,621	0,624



(Evolution of the risk score depending on the hazard score, along the different climate scenarios (exposure and vulnerability are assumed constant across scenarios)).

1.8.2.2 Results for Paris

The variation of the risk score from the baseline in 2020 to the projections in 2050 are very low. Indeed, it is inferior to 0.01 according to the arithmetic method, and equal to 0.01 according to the geometric one. This is essentially due to the stability of exposure and vulnerability, this last component mitigating the risk through its adaptive capacity. Hence, considering the current situation and the evolution of the risk score, the City should be able to absorb, even with difficulties, the additional population flow.

	Arithmetic (equally weighted)	Geometric (moment 1)
Baseline	0,60	0,63
Scenario 2.6	0,60	0,63
Scenario 4.5	0,60	0,63
Scenario 8.5	0,60	0,64

1.9 Towards adaptation at the city level

The final step in developing impact chains is identifying solutions and ways forward. The following questions can help identify a set of solutions and recommendations:

Box 9: Research questions adressed in that section

- **RQ1: Can examples from other contexts help to identify possible adaptation measures?**
- **RQ2: How can solutions build on "windows of opportunity" e.g. existing efforts and initiatives or leveraging existing partnerships?**
- **RQ3: Which structures or actors are needed to deliver and to contribute or support the delivery of these solutions?**
- **RQ4: Which decisions are critical to unpack further? Which need further support with climate – and other – information**

Main innovations: Co-production of knowledge and Integration of transboundary risks

These questions should be answered by speaking with stakeholders about relevant adaptation measures to be implemented at municipal level. To this end, a workshop was co-organized with the City of Paris (April 19th), bringing together stakeholders from academic, municipal, NGO spheres. This working paper links together elements from literature review and workshop outputs.

1.9.1 Migration profile for the City of Paris

Origins

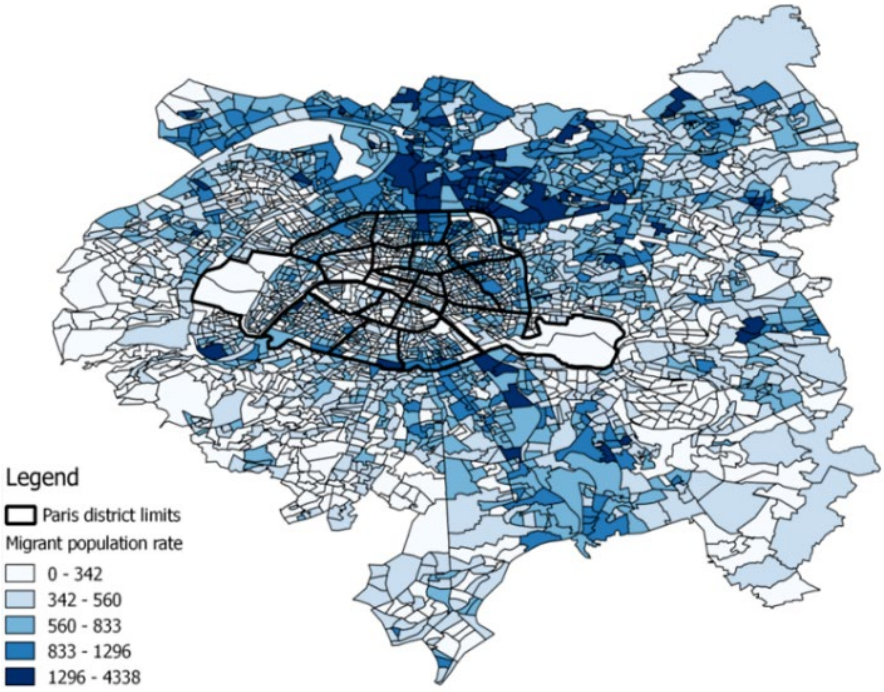
The foreign-born to overall population ratio is 13.1% in France, which is below the OECD average and below that of many EU peers. The number of asylum seekers and refuges steadily climbed, doubling between 2008 and 2015. A sharp surge was then observed in 2015, with the major nationalities being Sudan, Afghanistan, Haiti, Albania, Syria, Democratic Republic of Congo and Guinea. Around 38% of applicants are granted asylum (after appeals). This differs from the most commonplace nationalities of foreign-born immigrants in Paris: Algeria, China, Morocco, Portugal and Italy.

Causes for migration

In 2018, 55% of new immigrants obtained residence permits for family motives; 20% for humanitarian reasons; and 18% for professional reasons.

Integration

In terms of housing, immigrants are heavily concentrated in the North-eastern districts of Paris. Those having migrated for humanitarian reasons are most likely to be sheltered by acquaintances, in collective housing schemes, or in social housing. In Paris, 75% of homeless are migrants.



About 68% of migrants are employed in statistics collected the year following the attribution of their residence permit. 21% are unemployed, which is far higher than the national averages; obstacles to employment include weak French skills and knowledge of the labor market, and a workforce that is on average less skilled/qualified than the French population.

1.9.2 Pathways for adaptation

In the case of migration flows, there are several facets to the adaptation mechanism. On one hand, migration is considered an individual adaptation pathway for those leaving the country of origin. Better collective adaptation in the country of origin may lead to fewer out-migrations. Hence, the number of migrants is already a signal regarding the level of adaptation in the origin country. On the other hand, for the host country, adaptation to migration flows requires multiple layers of action, as put forward in the C40-MMC action agenda:

- Deliver an enabling policy environment
- Enhancing urban resilience, faced with climate hazards and displacement.
- Migrant integration: ensure the long-term integration of migrant population into the workforce and their access to social services and accommodations
- Urban transition: migrants participate in the transition towards a green, climate-friendly, and just city

1.9.2.1 Enabling policy environment

Nation-wide and regional policy

This case study is made more specific and complex by the fact that the city has several levels of administrative oversight: subject to national and regional scale policy, and holder of competencies at the departmental and municipal level.

There are few monitoring or policy tools specific to migrant integration, as integration policy is historically based on universal principles of equal treatment for all individuals. One exception is the Contract for Republican Integration (CRI, or CIR in French), promising residence permits in exchange for a commitment to upholding French values and attending language classes[10]. The State Department (Ministère de l'Intérieur), through the GEF directorate and the implementing agency OFII, is in charge of delivering residence permits and administrating the CIR.

City policy

Paris is solely responsible, both as a municipality and as a department, for some sectors that are key for integration such as welfare allocation, social action, cultural and local services, public spaces, etc. For housing, responsibility is shared between national programmes, which own social housing units and oversees regulations, and the city, which owns and builds social housing and allocates housing allowances[11].

Partnerships and best practices

On a small scale, partnerships have proven important to implementing effective actions for migrant integration. For instance, in the case of a humanitarian center for vulnerable refugee groups (CPA) which was opened in collaboration between Ivry-sur-Seine (location of the site) and Paris (owners of the site) [12].

On a wider scale, Mayors from across the globe have come together within the Mayors Migration Council (MMC), insistent that cities be recognized as key actors in managing climate migration and

[10] https://doi.org/10.1787/fa744789-en

[11] https://doi.org/10.1787/fa744789-en

[12] https://doi.org/10.1787/fa744789-en

advocating for unified policy and financing regimes around migration. The MMC supports mayors through knowledge-sharing, advocacy, and facilitating partnerships.

In collaboration with the C40, the MMC have built an action agenda outlining 10 principles to be followed at city level for inclusive action on climate and migration. Among these actions are to "Advocate for supportive national and international policies and direct funding to cities", and "engage in multi-stakeholder partnerships to address climate and migration challenges".

The MMC has also taken concrete action, for instance in the case of the Global Cities Fund for Inclusive Pandemic Response, of which Lima, Peru, became the first recipient. Lima has welcomed 600 000 Venezuelan refugees, out of the 800 000 who have found a new home in Peru. These migrants face significant challenges in terms of access to employment medical care, housing, and education, with access to childhood services especially important given that 47% of minors are younger than 5. Recognizing Lima's efforts in welcoming and integrating migrants, the US$ 1 million grant raised for the Global Cities Fund for Inclusive Pandemic Response was awarded to Lima. The Municipality plans to use the funds to open a Municipal Office of Service to Migrants Neighbors in a "gateway" neighborhood which typically is a first stop for migrants. This will allow newcomers access to a suite of services[13].

An analysis of Lima's local government also reveals several best practices. First, the presence of international organizations cooperating closely with the local government – as topical experts, they are effective in raising awareness about migrant needs. Next, the city participated in awareness raising campaigns with the private sector, gathering business owners and municipality agents to brainstorm on integration of vulnerable populations. Also, a municipality conducted public service requirements mapping, simply by including a 'nationality' information request in formal paperwork for accessing municipal services.

Relevant workshop outcomes

During the workshop, we reviewed a graph charting the institutional responsibilities for migrant integration. This exercise revealed a few shortcomings in the current organizational scheme. For instance, the Refugee coordination platform meant to coordinate action between different municipal departments and other actors (state or non-state), was cancelled following the last municipal elections, and is replaced by an information meeting. Hence, coordination between different entities is shifting and often lacking, even more so as much of the operational work is implemented by non-state actors.

[13] https://www.mayorsmigrationcouncil.org/gcf-res/lima-peru#:~:text=Lima%20was%20selected%20as%20a,IDPs)%20during%20Covid%2D19.

Recommendations:

- Building partnerships based on knowledge sharing (for the Direction de la transition écologique and the Becoming a part of the MMC (C40 application underway) could help expand the city toolbox and knowledge on climate migration matters.

- Monitoring migrant profiles to understand the dynamics of migration towards the city and the role of climate change. This could include simply exploiting results from surveys such as ELIPA 2 (conducted by INSEE) or pursuing initiatives such as IOM's case study on migrant integration in Paris.

- Improve policy coordination between the multiple and sometimes overlapping scales of governance; improve coordination and financing mechanisms between municipal actors and NGOs

- Clearer financial support for non-profit or NGOs which implement many of the actions necessary to migrant integration (first points of contact, enabling access to social services, emergency shelter, supporting job search, etc.)

1.9.2.2 Enhancing urban resilience

Urban resilience, in this context, refers to making cities resilient to climate change, and sheltering the inhabitants from its impacts. One of the major obstacles to both urban resilience and migrant integration is geographical segregation in urban centers, namely Paris. Socio-economic disparities are evident in Paris, with migrant populations heavily concentrated in Northern and Eastern districts. This concentration of wealth often leads to vulnerability factors being concentrated in one place, and leads to a cycle of vulnerability, as migrants do not have the means to protect themselves or housing against climate change, so become more vulnerable, etc.

The MMC-C40 action agenda calls for countries to significantly upgrade in planning and financing for urban climate adaptation - especially in low-income countries. Specific recommendations include:

- Devolve authority and build local capacity for urban and land use planning to enable effective adaptation and hazard mitigation strategies at the city level.
- Allocate 50 per cent of all climate finance for adaptation, including concessional finance, and support cities in attracting resilience investments to be channelled directly to the benefit of frontline, vulnerable, or marginalised communities.
- Facilitate municipal access to sustainable, adequate, and predictable finance for local climate adaptation, increasing intergovernmental fiscal transfers and direct funding and/or financing to cities.
- Expand support for the use of climate risk transfer mechanisms in urban contexts, including the development of subnational risk pools for local governments, catastrophe and resilience bonds, and micro-insurance for vulnerable households.

- Offer debt relief and incentives for investments in urban adaptation, including shock responsive social safety nets, through debt-swaps or by reimbursing external debt service for lower-income groups and countries that are vulnerable to climate change.

We examine whether existing strategies are effectively taking this direction, at city scale for Paris. The city of Paris approved its first Climate Plan in 2007, later setting up an Adaptation Strategy (2017). The vulnerability study which preceded the adaptation highlighted 5 hazards for the city of Paris: heatwaves (urban heat island effect), drought, floods, strain on food or energy supply, and biodiversity preservation. Actions to protect Parisians against extreme climate events include communication, contingency plans to maintain essential public services during emergencies, promulgating access to green (cool) spaces during heat waves, building water spray and shading infrastructures. To reinforce the resilience of power and communication grids, non-specified investments in modernizing equipments are promised. A third objective is to improve liveability in Paris under climate change conditions, through measures meant to improve access to water and green spaces and reduce energy consumption: reactivate fountains, add swimming pools, green public spaces in old and new constructions, implement passive cooling in new buildings, implement smart management of rainwater, protect buildings against flood risk. Several additional measures to improve planning are included: create a reference book for building in line with climate adaptation principles, launch the 'Plan Pluie Paris', add climate change considerations to the 'Plan Local d'Urbanisme'. Finally, a set of actions aim to make climate adaptation inclusive, through awareness-raising around individual behaviors for climate adaptation, developing cooperation between local city governments, promoting citizen solidarity initiatives, and better anticipating climate migrations.

In the context of the 100 Resilient Cities initiative, Paris also adopted a resilience strategy, of which climate change is one of the 6 dimensions. The Resilience strategy resolutely supports inclusion at local (neighborhood scales) and encourages building citizen networks, acting both against disasters and to remodel public spaces. It also states an intention to adapt infrastructure (schools, the power grid, public lighting, the beltway) and prepare 'resilient' green spaces, modeled after the Tåsinge Plads in Copenhagen, for instance.

Finally, it is important that the means match the ambitions. The Climate Plan showcases the ways in which the City of Paris intends to finance its so-called 'energy and ecological transition'. Among them:

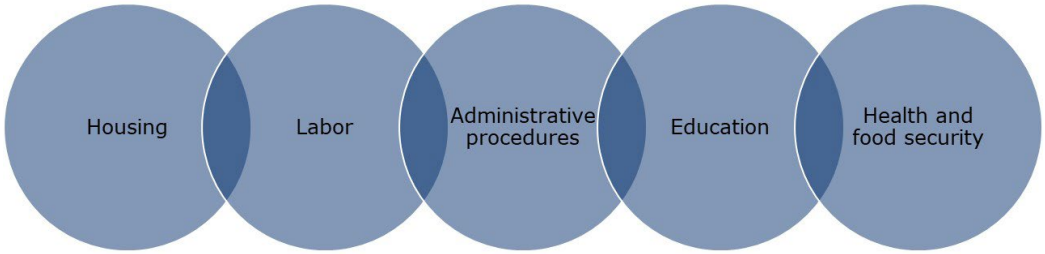
- undisclosed 'high rates of self-financing', enshrined in the current municipal programme and prolonged through the Municipal Investment Programme which includes a carbon neutral trajectory
- use of green bonds : 'Sustainability Bond' starting in 2017, and 'Resilience Bond' from 2020.
- For the renovation of public buildings, use of the Energy Efficiency Certificates Programme
- Consider an eco-loan scheme to support private property owners in renovating their buildings
- Territorial Investment Fund (Green Venture Capital Fund) to leverage private finance

- Develop green sponsorship

Taken together, these strategies provide a strong foundation for better urban resilience towards climate change. However, it is unclear to what extent their implementation has been prioritized, given that many actions were to be launched starting from 2020. Further, although inclusion is a keyword in both strategies, most actions depend on citizen goodwill and participation, rather than setting aside funding for vulnerable populations or areas. Similarly, actions meant to integrate different categories of populations (vulnerable vs less vulnerable) are perhaps underrepresented in the poorest neighborhoods. Key points include following up on the implementation of these plans (scaling up from the few pilot projects) and expanding the use of climate risk transfer mechanisms, namely ensuring that there are adequate insurance products available to citizens.

1.9.2.3 Migrant integration

Integration of migrants in, both in the short and the long-term, is key to ensuring stability and prosperity for the city and improving resilience of vulnerable communities to climate change. 'integration' is multi-dimensional and refers to migrants being able to access housing, employment, having access to social services, to education or vocational training, and to access health services.



The workshop held with actors from the city of Paris brought out several options for improving migrant integration in two key areas: housing and labor.

Housing

Access to decent housing is a key condition of both migrants' well-being and their social integration. This is one of the biggest challenges in the Paris area, in which the housing market is already strained and the cost of housing high. In Paris, over 25% of accommodations consist of social housing, but the imbalance between demand and supply leaves little wiggle room for accommodating more newcomers.

Several types of housing allowances are afforded by the City of Paris and accessible to migrants who hold a valid residence permit and are admitted as refugees or economic migrants. These funds are the Family Allowance Fund (CAF), the family allowance supporting households with children, and the social housing allowance. Applications for housing allowances can be completed online or in person at the Centres for Social Action (CASVP). These funds are widely accessible – about 17% of Paris' total population accessed one or the other in 2015. Next, as a Department, Paris allocates a Housing Solidarity Fund (FSL) which provides financial aid to help poor residents access housing

by taking on some of the costs (house deposits, real estate fees). The City Center for Social Action (CASVP) also supports vulnerable people with various housing needs (essential renovation), emergency housing solutions. Many emergency housing sites are operationally managed by non-profits or NGOs.

Workshop suggestions

In spite of these schemes destined to make housing affordable, the availability and cost of housing remains a major problem. Because the housing stock is finite and strained, prioritizing climate migrants or any category of vulnerable population for relocation is akin to relegating others (handicapped persons, refugees, etc.). As a consequence, most migrants arriving in Paris are dispatched rapidly to other regions of France with greater availability. This generates additional problems; as many will return to Paris in search of better opportunities or a community of fellow citizens; they are then ineligible for public assistance. More radical solutions mentioned include temporary seizing of private vacant housing. For short-term lodgings, ideas include partnerships with AirBnb or the traditional hotel sector or citizen participation.

Employment

Employment is essential to migrant integration. It is a pre-requisite to having a stable income, improving access to accommodations, and fully integrates migrants in the host society by allowing interactions with natives.

In the Île-de-France region, 18% of the migrant population was unemployed in 2014-2015, 5 percentage points more than the rate of unemployed natives (Source: OECD database on migrant population outcomes at TL2 level.). In the whole of France, the employment rate of recently arrived migrants is 25 percentage points lower than that of native-born. Only one out of three foreigners having lived in France for less than 5 years (working age) is employed.

Several reasons explain these figures. First, the language barrier: the ELIPA 2 study (2020) shows that around a third of recently admitted migrants have severe trouble communicating or even understanding French. Second, the workforce is on average less skilled compared to the French and especially Parisian workshop. Also mentioned during the workshop were some administrative barriers: foreigners applying for their first documentation papers are not allowed to work in the first 6 months, and even afterwards the procedures are complex. Finally, lack of accommodations and lack of employment negatively interact: it is difficult to hold a job while homeless, and conversely difficult to house oneself without stable income.

Solutions at City level include financial support to non-profit organizations promoting migrant employment (610 000 € in 2016). The city has also developed networks with the private sector to encourage employment of migrants and professional training. One example is the Forum for Diversity and First Employment, which targets job-seekers who have experienced or may be exposed to discrimination. A networking initiative was organized in the 12th arrondissement to coach employers in non-discriminatory practices, for instance.

Workshop suggestions

Skill matching initiatives were mentioned as a way to both improve migrant employment and meet employer needs in the region. Milan has set a 'best practice' precedent in this regard with their Centre for Job Orientation and Placement (CELAV), which is an innovative employment service tasked with the implementation of active labour market policies for the promotion of the professional and socio-economic inclusion of people in vulnerable situations, including migrants and asylum-seekers. Support is generally delivered through orientation services, provided through free-access information counters. The staff provide information on the type of jobs available in Milan and the skills sought by employers. Migrants may then be directed to other city services or pursue enhanced assistance by the CELAV to help with their job placement. The personal employment project often includes a traineeship to help develop needed skills.

Another pathway for action is to reform administrative constraints for working while awaiting judgement on residence permits.

Recommendations:

- Deploy skills-matching initiatives to facilitate employment of migrants, for instance following the CELAV model seen in Milan
- Maintain and develop community-mixing initiatives such as "Les Grands Voisins"
- Awareness-raising campaigns for non-discriminatory action
- Better monitoring systems on migrant arrival and presence to calibrate housing needs

1.9.2.4 Urban transition

Regarding urban transition, recommendations from the C40-MMC action agenda include:

- Promote inclusive and equitable climate action
- Deliver a just transition that provides good quality jobs to migrants and displaced people

Appendix 1: Involved stakeholders

City of Paris		Senegal	
Julie Roussel	Project leader for the adaptation strategy of the City of Paris	Adji Marieme Sow Diakhate	Direction for Analysis, Forecasting, and Agricultural Statistics
Noémie Fompeyrine	Parisian delegation for the resilience strategy	Robert Zougmoré	International Crops Research Institute for the Semi-Arid Tropics Climate Change, Agriculture and Food Security (CCAFS)
Thibault Bertrand	Apprentice in the Parisian resilience strategy	Seynabou Diouf	International Crops Research Institute for the Semi-Arid Tropics Climate Change, Agriculture and Food Security (CCAFS)
Anne-Charlotte Schneider	Project leader « Migrants and Refugees" in the Social Action Center of the City of Paris	Alassane Diallo	University of Dakar
François Gemenne	Expert researcher in political sciences		

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