Climate change induced risk to sustainable development and climate resilience of selected EU strategic partner countries

Deliverable 5.1

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RECEIPT project information	
Project full title	Remote Climate Effects and their Impact on European sustainability, Policy and Trade
Project acronym	RECEIPT
Grant agreement number	820712
Start date and duration	01/09/2019, 48 months
Website	www.climatestorylines.eu

Deliverable information	
Work package number	WP5
Work package title	International cooperation, development and resilience
Deliverable number	D5.1
Deliverable title	Report on co-created storylines on climate change induced risk to sustainable development and climate resilience of selected EU strategic partner countries
Description	This report describes the selection of hotspot areas within the EU strategic partnership built under WP5 Task 5.1
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Revision number	version 1.0 as on October 1st
Revision date	

Dissemination level of the document

X	PU	Public
	PP	Restricted to other programme participants
	RE	Restricted to a group specified by the consortium
	CO	Confidential, only for members of the consortium

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Versioning and contribution history			
Revision	Date	Modification	Author
v. 02	26/10/2020	Internal review	Bat van den Hurk
v. 03	26/10/2020	Internal review	Anton Orlov
v. 04	04/11/2020	Revisions section 1 and 2	S Marzi, J Pall, J Pellizzari
v. 05	09/11/2020	Revisions section 3	Christian Otto, Jacob Schewe, Patryk Kubiczek and Sven Willner

Approvals			
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Executive summary

This report describes the selection of hotspot areas within the EU strategic partnership built under WP5 Task 5.1. We have identified the countries involved in EU external action partnership through an exhaustive review of the available fact sheets outlined by the European External Action Service (EEAS) and by the Council of Europe Conclusions on Water Diplomacy, respectively in 2013 and 2018. We have adopted and extended the Index For Risk Management (INFORM Global Risk Index (GRI) to evaluate the projected climate risk as a product of hazard, exposure and vulnerability for EU external partners, and we determined the EU third party countries with highest exposure to climate-related hazards. Task 5.1 is constructed as a first screening of the global hotspots of remote areas, which are relevant for Europe through their connection pathways and sensitivity to climate change using the state-of-the-art climate and climate impact databases. The selection of hotspots ensures a focus on those areas and conditions that have had or are expected to have a noticeable impact on Europe, while providing a scientific assessment of their plausibility, legitimacy and relevance.

The storyline concept is central to the project; we aim to create plausible scenarios providing connected events and data to develop valuable storylines. The scope is to evaluate these storylines under the Paris Agreement scenarios. The process is strengthened by the engagement with societal partner organizations and by working closely with a larger number of scientific experts from societal and stakeholder organizations, such as the Internal Displacement Monitoring Centre (IDMC), the United Nations Office for Disaster Risk Reduction (UNISDRR) and the OECD High-level Risk Forum (HLRF).

In section 1, we provide an overview of the EU external action partners as the areas of interest, where we specifically concentrate in the European Neighbourhood Policy (ENP), Euro Mediterranean, Middle East and North Africa (MENA), the Africa, Caribbean and Pacific (ACP) regions and the Latin America geographical domains.

In section 2, we identify the remote hotspots affected by assessing climate-related risks comprised of hazard, exposure and vulnerability for the countries involved in EU external action partnerships. To do so, we extend the INFORM Global Risk Index (GRI), developed by Joint Research Centre (JRC) / European Commission Disaster Risk Management Knowledge Centre (DRMKC), to include the latest Intergovernmental Panel on Climate Change (IPCC) modelling projections with a focus on drought, river and coastal flood hazards and accounting for exposure and vulnerability.

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In section 3, we developed three storylines for hotspot regions identified by the extend INFORM GRI analysis: two on food security and one on internal displacement. The first food security storyline (FS1) assesses food insecurities in North and East Africa as well as the Horn of Africa; and the second food security storyline (FS2) addresses the additional impacts of potential regional increase in drought frequency on the stability of the global food web and food security in the Horn of Africa region. The third storyline (DD1) deals with flood induced displacement in the Horn of Africa.

The initial selection of hotspot areas will be used later in the next WP5 Task 5.3 to assess the storylines for currents impacts on development, resiliency and security in EU partner countries. The implications on food security and displacement (cf. Sec. 3) based on the initial selection of hotspot countries are central for WP5 Task 5.2 in building the storylines. To assess how climate change will impact the stability of the global food web in general and food security in the focus regions in particular, we will employ the agent-based network model Agrimate designed to complement well established agricultural market models such as GLOBIOM[1] (cf. analyses in WP3) by explicitly resolving short-term supply failures.

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1 EU External Actions and partnerships

The RECEIPT WP5 focuses on climate risks within the context of European external actions, international cooperation and development. It aims to explore climate risks affecting the EU strategic partners and aids them in developing strategies and capacity to cope with them. According to the UN Development Agenda 2030, the EU and its Member States are committed to respond to current global challenges applying the EU Global Strategy and prioritizing EU external actions at all levels, especially in addressing the lack of management of climate-related risks in developing countries.

To gain an in-depth understanding of the areas highly affected by climate change in the water sector, INFORM GRI is extended and applied to measure the hazard, exposure and vulnerability. We take into consideration the risks associated with river floods, coastal floods and droughts for the EU partner countries in water diplomacy together with the extent at which the EU partners are exposed to each country's climate change vulnerability. Our overall goal is to predict socio-political-economic measures that EU partner countries can pursue through the identification of EU partners in the water sector, together with the risk and vulnerability assessments applying INFORM GRI to account for projected climate and population change.

The choice of the hotspot selection within WP5 is based on the tailored methodological framework offered by INFORM GRI extended to include climate change projections (Section 2). Based on this framework, the hotspot countries and their impacts on water diplomacy and water policy dialogue are evaluated with a specific focus on the countries within the ENP, MENA and Africa, and the ACP regions. In subset of these hotspot countries, projections on food security risks and internal population displacement risks due to natural disasters are determined using Acclimate (Section 3).

1.1 Scope and focus

The European Union's action on the international scene highlights its strategic interests and objectives through its international action; it supports development, cooperation and political dialogue with countries in the Mediterranean, the Middle East, Asia, Latin America, Eastern Europe, central Asia, the western Balkans and others. The EU's Policy strategy is to cooperate internationally and to support foreign countries to achieve sustainable development. The European Development Fund (EFD) was established to eradicate poverty with a focus on developing countries, especially in the ACP[2]. The EU is recognized as the *world's leading aid*

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donor with more than €74 billion invested in 2018 for development aid[2]. The EU has mainly focused on the ACP regions, Asia, its Eastern and Southern neighbours, and Latin America. It represents one of the main international leaders in policy coherence, and for this reason it has actively participated in delineating a report for the UN 2020 Agenda for Sustainable Development Goals (SDGs)[3]. After the UN approval, the EU revised its European Consensus on Development latest version, delineating a new strategy for the achievement of the SDGs[2]. In addition, the EU adopted the EU Agenda for Change that aims for sustainable development growth and the advancement of human rights, democracy and good governance in Europe[2].

The European External Action Service (EEAS) is the EU's diplomatic service, which brings together the EU institutions and the Member States' foreign affairs and defence ministries. The Common Foreign and Security Policy (CFSP) was first established by the Maastricht Treaty in order to strengthen international security, foster international cooperation and promote democracy within the neighbour countries in Europe, building upon the principles on human rights and freedom. The CSFP duties are performed by parliamentary delegations. To date, there are 44 interparliamentary delegations[4]. In particular, the ACP-EU Joint Parliamentary Assembly couples members of the European Parliament (MEPs) and the elected representatives of the ACP countries, both of which are signatories of the Cotonou Agreement[4]. The EuroNest parliamentary assembly (PA) is the parliamentary forum of the EU's Eastern Partnership[4].

The European Neighbourhood Policy is a partnership between the EU and its Eastern and Southern neighbours that aims to foster prosperity, strengthen the political stability and reinforce the national security of its partners. It is based on Article 8 of the Treaty on European Union and on Articles 206-207 (trade) and 216-219 (international agreements) of the Treaty on the Functioning of the European Union (TFEU)[5]. The ENP partnership depends on Partnership and Cooperation Agreements (PCAs) and Association Agreements (AAs)[5] with primary objectives to assure mutual engagement to achieve sustainable development and to adhere to common principles. In doing so, the EU provides financial tools to the ENP countries through the access of the European Neighbourhood Instrument (ENI), the Civil Society Facility and the support of the EU's Commission financial partners, such as the European Investment Bank[5].

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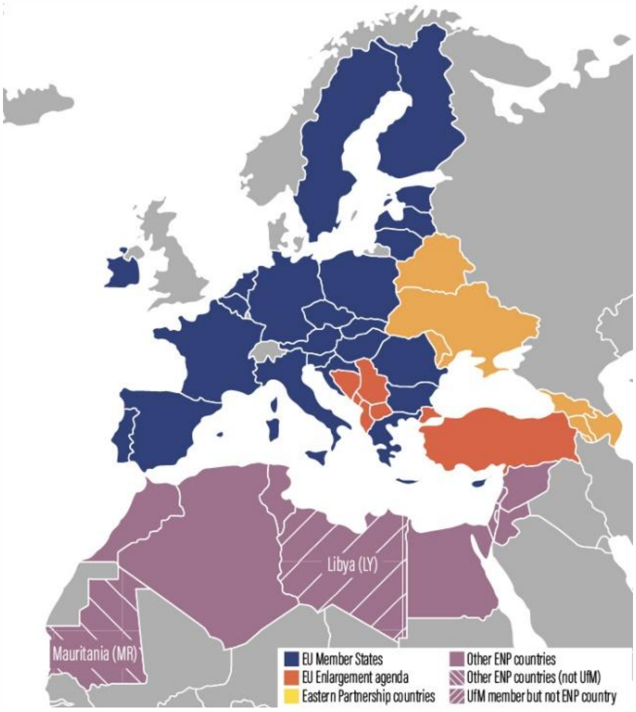

Figure 1 Overview of the European Neighbourhood Policy countries

The EU enlargement agenda includes Turkey, Albania, Bosnia and Herzegovina, Kosovo, North Macedonia, Montenegro and Serbia.

Eastern partners include Armenia, Azerbaijan, Belarus, Georgia, Moldova and the Ukraine

Southern partners include Algeria, Egypt, Israel, Jordan, Lebanon, Libya, Morocco, Palestine, Syria and Tunisia.

The UfM consists of the EU MSs, the EU and 15 Mediterranean countries: Albania, Algeria, Bosnia and Herzegovina, Egypt, Israel, Jordan, Lebanon, Mauritania, Montenegro, Monaco, Morocco, Palestine, Syria (currently suspended), Tunisia and Turkey.

1.2 Strategic partnerships

The RECEIPT WP5 on international cooperation and development aims to explores how future climate variability and change can undermine development, competitiveness, stability and resilience of countries with which the EU maintains strategic partnership relations. This subsection provides an overview of the primary partnerships that the EU has with third-party countries, and it highlights the importance and benefit they have in partnering together. Our overview focuses on the Eastern and Southern partners, the MENA countries and the ACP states. As ACP nations are vital partners for the EU, additional emphasis is dedicated to the key partnership of the EU-ACP Cotonou Agreement. Their foreign relations will play a critical role determining the future of Europe and Africa in socio-economic and political terms under several aspects, especially humanitarian aid, sustainable development and disaster risk governance of climate-related risks.

Eastern partners: The European Eastern partners are Armenia, Azerbaijan, Belarus, Georgia, Moldova and the Ukraine. The primary objective of the EU - Eastern Partnerships (EaP) is to foster the level of integration and cooperation with each eastern neighbour. The EaP goals are to assure the promotion of democracy and good governance, strengthen of energy and

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environmental security, encourage sectoral reforms, support economic and social development, reduce socio-economic imbalances and increase political stability[5].

Southern partners: The partners countries are Algeria, Egypt, Israel, Jordan, Lebanon, Libya, Morocco, Palestine, Syria and Tunisia. It consists of bilateral policies between the EU and the individual partner countries, plus the Union for the Mediterranean (UfM) which is a regional cooperation framework launched in 2008 to revive the Euro-Mediterranean Partnership[6]. The UfM promotes economic integration and political development across 15 neighbours to the EU's south in North Africa, the Middle East and the Balkans region: Albania, Algeria, Bosnia and Herzegovina, Egypt, Israel, Jordan, Lebanon, Libya (observer), Mauritania, Monaco, Montenegro, Morocco, Palestine, Syria (suspended), Tunisia and Turkey[7].

ENP for Climate Change: Central to the ENP are the bilateral ENP Action Plans agreed upon between the EU and each partner, which put forth an agenda of priorities for political and economic reforms. The main foci of the ENP Action Plans are the environment, especially climate change, energy, transport and sustainable development[8]. The EU's efforts to help partners to tackle climate change and environmental issues take different actions, such as in providing financial assistance and collaborating on specific research projects under the Horizon 2020 Framework. In addition, the ENP Action Plans aims to support partner countries through environmental technical tools to improve decision-making through better data collection and to increase stakeholder participation. To date, bilateral and multilateral projects based on sustainable development and environmental protection have netted positive results for the EU Eastern and Southern partners[8].

EU – Central Asia Partnership[9]: The EU – Central Asia Partnership, formed in 2007, is a strategic partnership focusing on transboundary water diplomacy between Europe and Central Asia countries to facilitate the dialogue on water shared resources. The establishment of the Central Asia Regional Economic Cooperation (CAREC) Program is the result of this collaboration which has the main goal to increase collaboration and cooperation in water and energy. In 2019 the Council of Europe adopted a new EU strategy in Central Asia defining new policies to promote regional cooperation with partners countries. The EU and CA agreed upon the Water and Environment Cooperation Platform (WECOOP) in 2009 to strengthen policy dialogue and cooperation in water management at the regional level.

EU – MENA Partnership: The EU - MENA Partnership focuses on rivers, basins and lakes, for the management of transboundary water resources in the Middle East and Northern Africa regions. In 2002, the EU and Africa settled the EU – Africa Water Partnership[10] for water and sanitation, creating the Africa – EU Water partnership project (AEWPP) to provide financial

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assistance and implement water infrastructures, and to support national government investment in water governance through capacity building and institutional development. The EU is Africa's main partner, and they work together to tackle common challenges, from investing in youth, fostering sustainable development and strengthening peace and security to boosting investment in the African continent, implementing good governance and improving managed migration. The EU is Africa's biggest partner with €2.7 billion of grants for sustainable energy projects and €4.2 billion for the period 2014-2020 for actions related to food and nutrition security, and sustainable agriculture and fisheries in Africa. The Eu is also the biggest contributor of climate financing providing €20.2 billion in 2016 alone.

EU – India Water Partnership[11]: Established in 2017, the EU – India Water Partnership aims to facilitate the management of natural resources in areas affected by challenges associated with water quantity (scarcity, droughts and floods) and water quality (industrial, urban and agricultural pollution). India is looking for sustainable management solutions for catchment areas to secure water use for its economic, agricultural and industrial growth. In the 2015 and 2016 EU - India Water Forums, three projects working on river basin management planning and governance; water allocation, water economics and flows in river basin management; and technical exchange in river basin management planning were established to mark the path for stronger collaboration.

EU - China Partnership: The EU - China Partnership, established in 2012 as a result of the China – Europe Water Platform (CEWP)[12], has the objective to promote policy dialogue and business development in the water sector to ameliorate difficulties in the economic development of and in threats to its natural resources. In 2019 the EU Commission advocated that China-EU Water Policy Dialogue deepen the EU-China water cooperation, allowing partners to exchange information and experience and to provide political drive and support for the China-Europe Water Platform outcomes. The Commission supports the work of this platform through a €6 million Partnership Instrument project that addresses, for example, water policies, integrated water resources management, adaptation to climate change, water disaster mitigation, protection of water ecosystems and cooperation through joint programmes on applied research and business cooperation. In addition, the EU – China 2020 Strategic Agenda for Cooperation aimed to strengthen the CEWP to address water scarcity, water use efficiency, water quality and water disasters.

EU – Latin America Partnership[13]: The Latin American Network of Centres of Excellence in Water (RALCEA) project is a capacity building programme that aims to promote policies based on sound information and evidence in the water sector by supporting the development of a

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network of knowledge centres. From 2010 to 2015, the European Commission provided a total of €2.25 million budget to the projects[14]. The WATERCLIMA Latin America and Caribbean (LAC) programme improves watershed and coastal management for climate change adaptation. Since 2014, this programme has been implemented in the Latin American and Caribbean region with a total projected budget of €8.7 million, of which €7 million granted by the Commission[15]. In addition, the EU - Cuba relations[16] represent one of Cuba's first development cooperation partners. Since 2008, the EU has committed over €200 million of support to Cuba for development in priority sectors such as sustainable agriculture and food security, the environment, renewable energy and climate change. The EU and Mexico relations are strengthened by their partnership based on common principles and objectives: democracy, resilience, prosperity and good governance[5]. One of the areas of dialogue and cooperation focuses on the environment, climate change and energy.

The EU - CELAC Partnership[18]: The Community of Latin American and Caribbean States (CELAC), inaugurated in 2011, represents a regional political coordination mechanism that gathers all Latin American and Caribbean countries. Climate change is one of the main thematic areas of cooperation with both dedicated programmes and crosscutting actions. The EU and CELAC countries have a regular dialogue in the multilateral forums on climate change. The EUROCLIMA+, launched in 2015, is a good example of partnership and tailor-made regional cooperation between the EU and Latin America. Its objective is to promote environmentally sustainable and more climate-resilient development in 18 Latin American countries with a focus on vulnerable populations.

EU – ACP Partnership[19]: The ACP and Europe has a strategic partnerships build upon bilateral and multilateral development agreement such as the Marshall Plan with Africa[20] which comprise joint efforts to develop National Determined Contributions with mitigation and adaptation strategies to cope with climate change impacts at the national level. The EU's relations with Africa are a key priority for the new European Commission[103] enhancing state and societal resilience in ACP. The EU created an ACP - EU Water Facility in 2004 as a funding scheme to support water and sanitation services in African, Caribbean and Pacific countries. It aims to achieve the Drinking Water and Sanitation Target of the Millennium Development Goals (MDGs) and to improve water governance and water resources management for the sustainability of water infrastructure. The ACP - EU Water Facility works on three main activities: Water, Sanitation and Hygiene (WASH) Promotion for the MDGs; partnerships for capacity development in water and sanitation sector; and sanitation in rural and urban areas.

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SEA – Europe Joint Funding Scheme (JFS)[21]: The SEA – Europe Joint Funding Scheme (JFS) is a European initiative in collaboration with Southeast Asia countries and an instrument to provide funding on regional research projects at the national, regional and local levels in Southeast Asia and Europe. The core focus of the projects is on environment, climate change and health. The JFS is managed by the EU Commission's Service facility in Support of the Strategic Development of International Cooperation in Research and Innovation.

1.3 The EU-ACP Cotonou Agreement

The EU holds a longstanding cooperation with the ACP countries which is demonstrated by agreements established since the first Lomé Convention in 1975. The EU signed the Cotonou Partnership Agreement (CPA) with the ACP countries in 2000 for a twenty-year period, demonstrating its interest to reinforce the diplomatic relations. The CPA addressed several policy areas under three pillars: the political dimension, economic and trade cooperation, and development cooperation. Its objective was to promote the economic, cultural and social development of the ACP States, while contributing to peace and security, and to foster a stable political environment. This EU-ACP partnership is constructed by a legally binding system, and it is exercised on the basis of fundamental principles, such as equity, participation, dialogue, differentiation and regionalisation[22]. It underscores the need for social cohesion, the importance of an active and organised civil society, and the reinforcement of the foundations of sustainable management of natural resources and the environment with a focus on climate change. Particular emphasis is placed on i) mainstreaming environmental sustainability into all aspects of development cooperation and support programmes and projects; ii) strengthening the scientific and technical human and institutional capacity for environmental management for all environmental stakeholders; iii) supporting specific measures and schemes aimed at addressing critical sustainable management issues; and iv) addressing issues related to the transport and disposal of hazardous waste [22]. The CPA, which ended in February 2020, represented one of the most extensive agreements signed by the EU with developing countries. Efforts are underway to form a new agreement.

The European Development Fund (EDF) represents the main financial instrument for providing development and support humanitarian interventions in cases of emergencies and unpredictable events for ACP countries[23]. The EU's previous evaluations have demonstrated that the instruments at the national and regional level are proven to be overall positive in supporting local needs. However, the lack of effective governance and management at the

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regional level due to complex administrative procedures and the absence of adequate staff still remain, representing one of the main challenges.

The EU has started to delineate a new cooperation with ACP countries. The EU Commission and the European External Action Service (EEAS) has proposed to structure the renewed partnership around five key areas: i) the development of a green transition and access to energy; ii) a digital transformation; iii) sustainable growth and jobs; iv) peace and governance; and v) the improvement on migration and mobility[24]. Its main objectives will address specific challenges, such as the action against climate change and the transition to a green economy and a digital transformation; the increase in investments at the socio-financial level; the attraction of new investors to support the business environment; the reinforcement of human rights, especially for youth and women; and the strengthening of good governance and democracy. The EU-African Union Summit was meant to take place in Brussels in October 2020, however due to the COVID-19 pandemic, it has been postponed to sometime in 2021. The Summit will represent a unique opportunity to establish joint priorities for a common future between African countries and the EU, and to enhance their diplomatic dialogue.

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2 Climate Change Risk and Vulnerability

Climate change is one of the major drivers of disasters losses and failed development, affecting the security and well-being of communities. In recent years, climate-related risks have been amplified as a result of climate change, unplanned urbanization, demographic pressures, land-use and land-cover change, biodiversity loss, and eco-system degradation[25–27]. According to the IPCC 2018 special report on global warming of 1.5℃, the threshold of limiting global warming increase to 1.5 above pre-industrial levels (Paris Agreement cap) will be surpassed in the late 2030s or early 2040s. Under the high-end atmospheric GHG concentrations scenario in which the countries fail to mitigate GHG emissions (RCP 8.5), the warming is likely to be in the range of 2.6 – 4.8℃ by the end of the century and considerably higher over land[28,29]. The projected warming is expected to lead to non-linear changes in intensity and frequency of several hazards such as river floods[30,31], coastal floods (storm surges)[32], droughts and heatwaves[28,33].

Risk reduction processes have multiple inter-connections with climate change mitigation, adaptation and vulnerability reduction which shall be accounted in DRR plans. Therefore, integrated approaches implementing centralized strategic and instrumental measures among DRR, CCA and development planning are required to adapt to and reduce risk of climate change, from shorter-term risks imposed by natural and man-made hazards and related biological, technological and environmental hazards and risks. According to *Global Assessment Report on Disaster Risk Reduction,* "Failure to include climate change scenarios in assessment and risk reduction planning will build inherent redundancy in all we do"[29,34,35].

In this research, we extend INFORM GRI to include projected climate change amplified hazards (river flood, coastal flood and droughts), projected population change (exposure) and vulnerability (lack of coping capacity). Through this analysis, we can explore how future climate variability and change can undermine development, competitiveness, stability and resilience of countries with which the EU maintains strategic partnership relations.

2.1 INFORM Global Risk Index 2020

INFORM GRI 2020 is a composite country-level indicator developed by the Joint Research Centre as a tool for understanding the risk of humanitarian crisis and disasters[36,37]. The INFORM initiative started in 2012 as a convergence of interests of UN agencies, donors, NGOs and

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research institutions to launch a common evidence-based tool for global humanitarian risk screening The INFORM framework envisages three dimensions of risk: i) Hazards and Exposure – events that could occur and exposure to them; ii) Vulnerability – susceptibility of communities to those hazards; and iii) Lack of Coping Capacity – lack of resources available that can alleviate the impact (Figure 2)[37–40]. The INFORM model is split into various sub-levels to provide a quick overview of the underlying drivers of the humanitarian risk. Overall, a total of 61 indicators have been used for INFORM GRI and six reports have been produced in consecutive years (2015-2020).

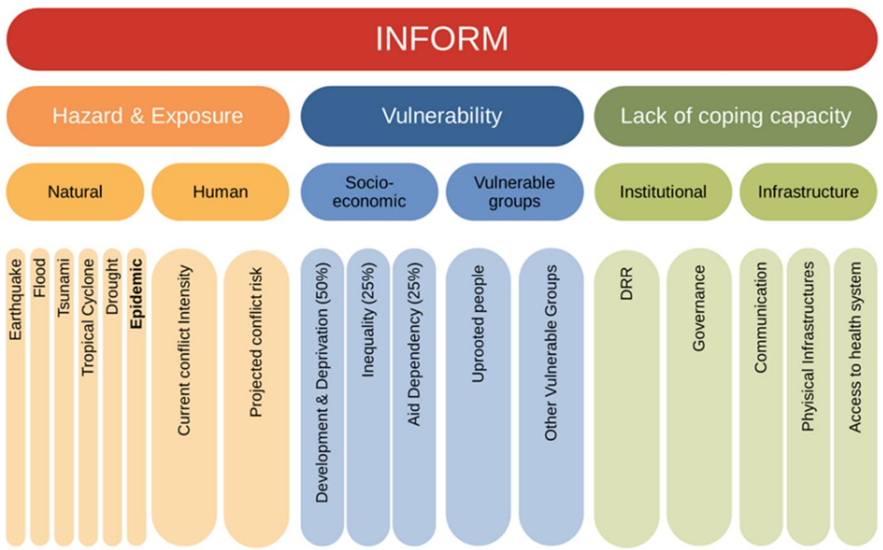

Figure 2. Overview of the INFORM GRI components[37].

In INFORM GRI 2020, the vulnerability and lack of coping capacity indicators are based on the year with the latest data. The hazard and exposure data are calculated based on probabilistic hazard maps using different return periods combined with population for the latest available year. INFORM GRI considers population as the only exposed element to both natural and anthropogenic hazards. Six main natural hazards are included in the analysis: earthquakes, tsunamis, floods, tropical cyclones, droughts and epidemics. The anthropogenic hazard encompasses both conflict intensity in a country or an estimate of future conflict probability[41] and projected risk of conflict within the next 4 years[42].

The vulnerability dimension of INFORM encompasses socioeconomic vulnerability and vulnerable groups. Socioeconomic vulnerability is comprised of development and deprivation, inequality and aid dependency. The Vulnerable groups category refers to “the population that has specific characteristics which make it at a higher risk of needing

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humanitarian assistance than others or being excluded from financial and social services", which is frequently defined as social vulnerability in the literature[43,44]. It is comprised of uprooted people (refugees and displaced population) and other vulnerable groups identified based on health conditions, age dependency and food security. The lack of coping capacity dimension is composed of institutional and infrastructure components. The institutional component evaluates the efficacy of government in perusing Disaster Risk Reduction (DRR) activities and contains DRR and governance factors. The infrastructure component is a combination of communication, physical infrastructures and access to health systems[37].

The INFORM GRI 2020 hazard and exposure, vulnerability, lack of coping capacity and risk indices are illustrated in Figure 3 for the countries involved in a strategic partnership with the European Union. The indices help provide a means to objectively allocate resources for disaster management as well as for coordinated actions focused on anticipating, mitigating, and preparing for humanitarian emergencies. Currently, INFORM GRI only considers historical data and not climate change projections. According to the recent INFORM GRI's Impact Survey[45], integrating climate change projections and future climate change adaptation (CCA) measures in INFORM GRI (described below) will likely be of great benefit to its partners.

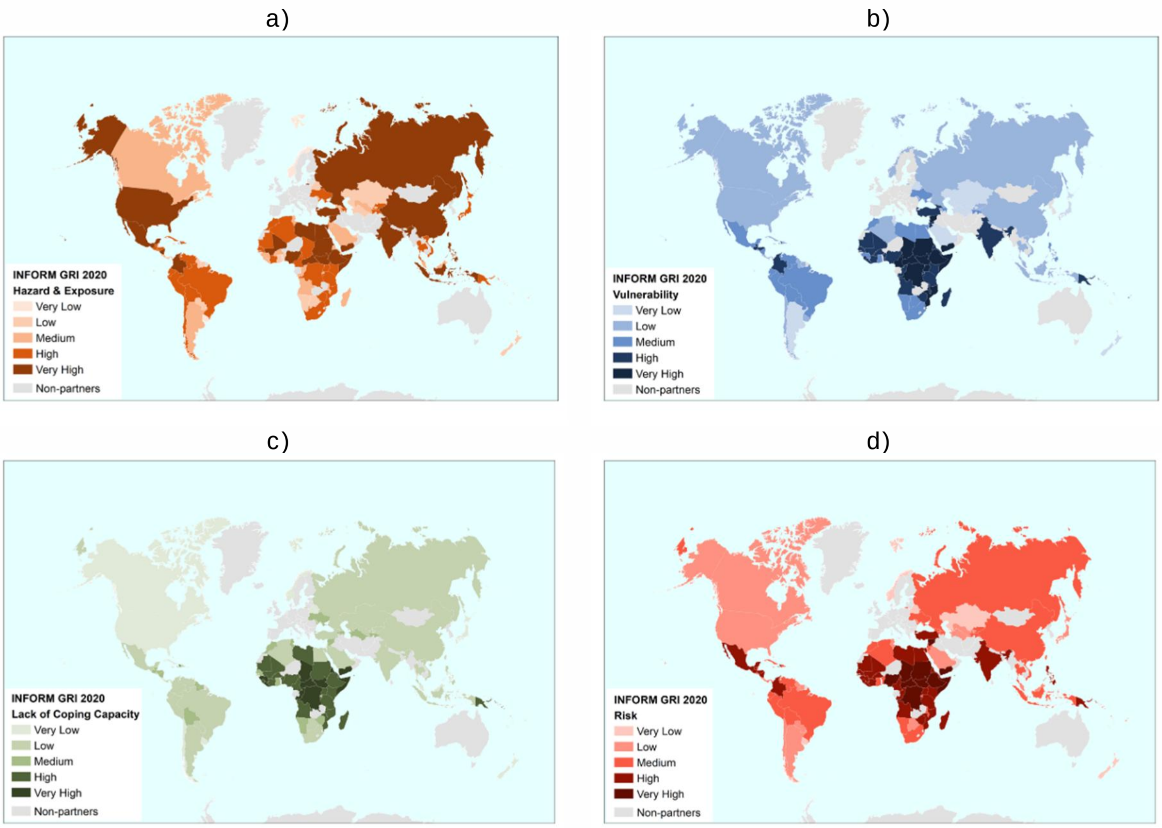

Figure 3. INFORM GRI 2020: a) hazard & exposure; b) vulnerability; c) lack of coping capacity and d) risk indices for EU partners.

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2.2 Extended INFORM Global Risk Index

In this section, INFORM GRI is extended to include projected climate change amplified hazards (river flood, coastal flood and droughts) through the year 2065. Current coverage of climate-related hazards in INFORM RISK is based on i) UNISDR Global Risk Assessment (GAR 2015)[46], ii) FAO Agricultural Stress Index (ASI)[47], iii) Emergency Events Database (EM-DAT)[48] and iv) The Global Seismic Hazard Map (GSHAP) [49] data, for different hazard intensities. In the extended INFORM GRI, the hazard and dimensions are accounted for using projections based on IPCC Representative Concentration Pathways (RCPs) and corresponding Shared Socioeconomic Pathways (SSP) scenarios for the mid-21st century (2036-2065). Three INFORM GRI 2020 hazards are modified based for use with output from climate change and impacts models (Table 1).

Table 1. Overview of the current and proposed coverage of hazards and risk.

Hazards	Current	Extension for RCP8.5 & SSP3 Projections (2036-2065)
Riverine Floods	Expected annual exposed population by GAR2015 global flood hazard maps for different intensities/probabilities.	Expected annual exposed population based on Global Flood Awareness Systems (GLOFAS) hazard maps [50,51].
Storm surge	Expected annual exposed population by GAR2015 storm surge	Probabilistic coastal flood projections of extreme sea levels (combined mean sea level, tides, wind-waves, and storm surges) [32].
Droughts	Observed number of droughts (based on Agricultural Stress Index (ASI) from FAO) [47] and population affected (EMDAT)	Frequency of drought using the Standardized Precipitation-Evapotranspiration Index (SPEI) [52,53] based on precipitation and minimum and maximum temperature from statistically downscaled CMIP5 simulations.

The analysis encompasses three main steps: i) assess the projected change in GRI due to only in hazard (single/multi-hazard) resulting from climate change (Figure 4a); ii) assess the change in GRI due to both projected hazard and population exposure (Figure 4b); and iii) estimate the increase in coping capacity (decrease in vulnerability) required to compensate for the increase in projected hazard and exposure (Figure 4c). For all of the hazards, we compute the projected population exposed for the mid 21st century (2036 to 2065) considering both the projected SSP population estimates (combined hazard and population change) and the fixed 2015 population (hazard change alone).

For this project, we consider RCP 8.5 which is the pathway with the greatest atmospheric GHG concentrations and represented by 8.5 W m^{-2} global radiative forcing by 2100. Kebede *et al.* (2018) suggest that by considering RCP 8.5, we can maximize the sampling of uncertainty in future climate changes and provide a challenging yet plausible scenario context to test the

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robustness of human and natural systems and climate change adaptation measures. Nevertheless, while the RCP 8.5 GHG concentrations are considered to be relatively high, there is little difference between other RCP scenario concentrations in the early and mid-21st century.

a) change in risk due to amplified hazard (H)	b) change in risk due to amplified hazard (H) and exposure (E)	c) degree of reduction in vulnerability/lack of coping capacity (V) necessary to maintain the current risk magnitude

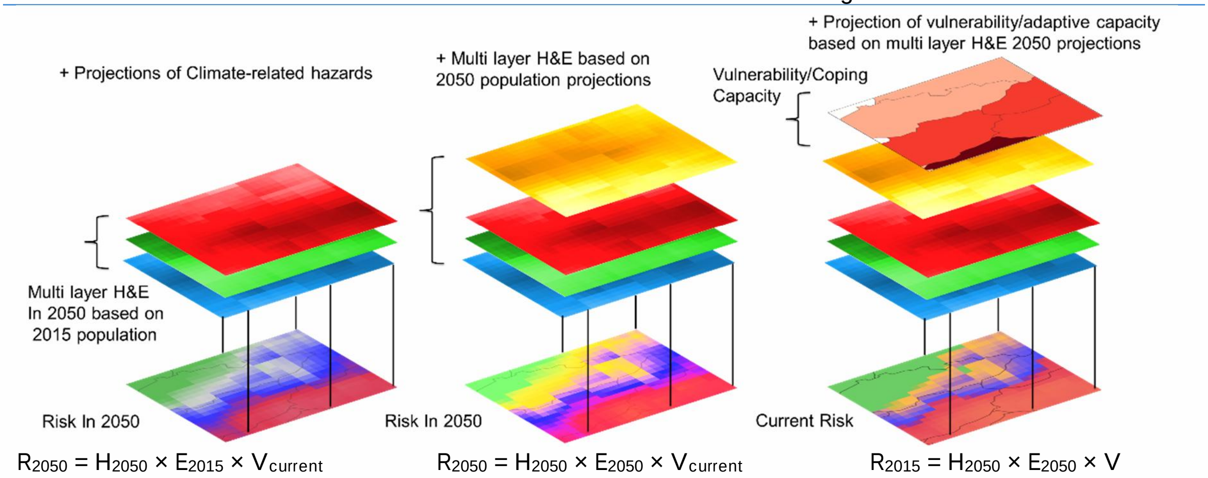

Figure 4. INFORM Risk (R) analysis stages including the components of hazard (H), exposure (E) and vulnerability/lack of coping capacity (V).

To evaluate the exposure components, SSP3 population projection is used[55,56]. SSP3 (fragmentation) envisages relatively low-income growth and low investments in human capital, relatively high fertility and population growth rates in the currently high fertility countries, and low fertility rates and low population growth (or decline) in the currently low fertility countries; migration is relatively low, and urbanization proceeds slowly[44]. Van Vuuren *et al.* (2014) developed a scenario matrix to address the effectiveness of various RCP-SSP combinations for the year 2100 using different integrated assessment modelling teams. By accounting for the uncertainty associated with the different possible interpretations of the SSPs by different integrated assessment modelling teams, they found that RCP 8.5 could be combined with SSP2, SSP3 and SSP5. Nevertheless, according to IPCC 2018 special report at higher risk thresholds (RCP 8.5) the world's poorest populations are expected to be disproportionately impacted, particularly in cases (SSP3) of great inequality in Africa and southern Asia[58]. In addition, a higher tendency towards regional fragmentation is projected between now and 2050[59,60]. Hence, we consider SSP3 (Fragmentation) coupled with RCP 8.5.

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Under SSP3, the total number of people is projected to increase from 7.1 billion in 2015 (2015 Global Human Settlement Layer (GHSL)) to 9.8 billion in 2050 (36.7% growth) (Figure 5). At a regional scale, population is projected to change from 4.2 billion in 2015 to 5.5 billion in 2050 (+30.2%) in Asia; 1.1 to 2.3 billion (+97%) in Africa; 615 to 839 million (+36.3%) in Latin America and Caribbean; 312 to 324 million (+3.6%) in North America; 729 to 669 million (-7.3%) in Europe; and 35 to 47 million (+33.9%) in Oceania.

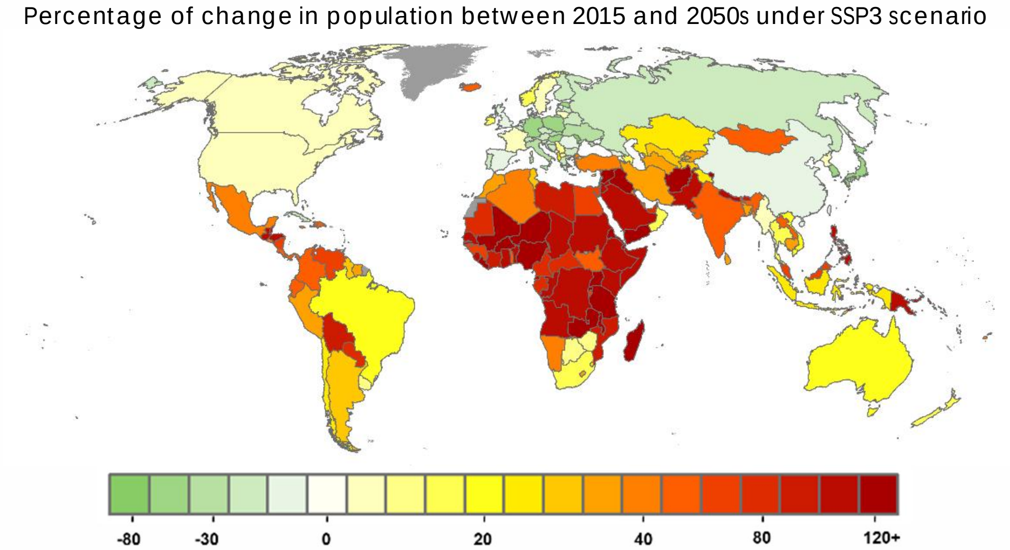

Figure 5. Projected population change under SSP3 compared to GHSL 2015[56].

2.2.1 River flood Exposure

For river floods we consider expected annual population estimated using Global Flood Awareness Systems (GLOFAS) hazard maps[50,51,61] for RCP 8.5 and SSP3. The hazard projections are based on a modelling cascade involving hydrological, hydraulic and socioeconomic impact simulations, and making use of state-of-the-art 1-km grid resolution hazard and exposure data (GHSL 2015 population). An ensemble of seven high-resolution global climate projections is used to derive streamflow simulations for the historical and future climate. The simulation output is analysed to assess the frequency and magnitude of river floods and their impacts under several climate change scenarios including RCP 8.5 for the mid 21st century (2036 to 2065) presented here[61].

Globally, 130 million people are projected to be exposed to river floods in the 2050s (+141%) considering no population growth (i.e. with population fixed at 2015 levels) and 174 million people (+233%) under the SSP3 population projection (Figure *6* and Table *2*). Regionally, the largest absolute exposed population is projected in Asia, with 103 million people exposed (+193%) with no population growth and 133.6 million people (+279%) under SSP3. However, the

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largest percentage of change in exposed population is projected in South America with a 296% increase with fixed population and 427% under SSP3.

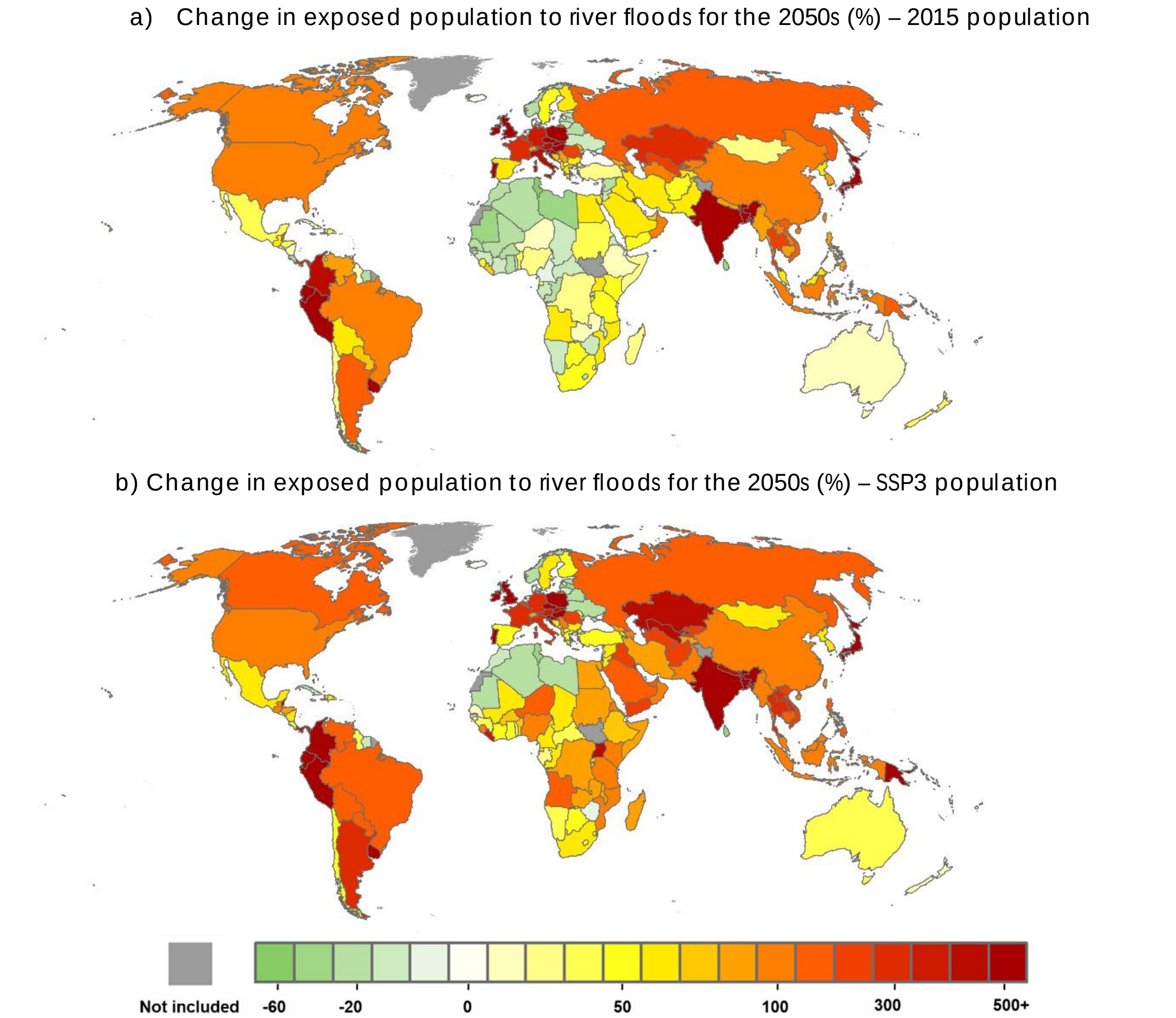

Figure 6. River floods projections: percent change (%) between the baseline data (1976-2005) and the projections (2036-2065) with a) population fixed to the 2015 values; and b) SSP3 population estimates.

2.2.2 Coastal Flood Exposure

For the storm surge component of the extended INFORM GRI, we use the probabilistic coastal flood simulations of extreme sea levels (ESL) for different return periods (5, 10, 20, 50, 200, 500, and 1000 year events) for RCP 8.5 for the mid-century provided by JRC[32]. ESL combines mean sea level, tides, wind-waves and storm surges. In their analysis, rising ESLs are primarily driven by thermal expansion, followed by contributions from ice mass-loss from glaciers and ice sheets in Greenland and Antarctica. They use atmospheric forcing from a 6-member CMIP5 Global Climate Model (GCM) ensemble to calculate projections of waves and storm surges as well as their changes in relation to the historical period (1980–2014). In addition, they assess the

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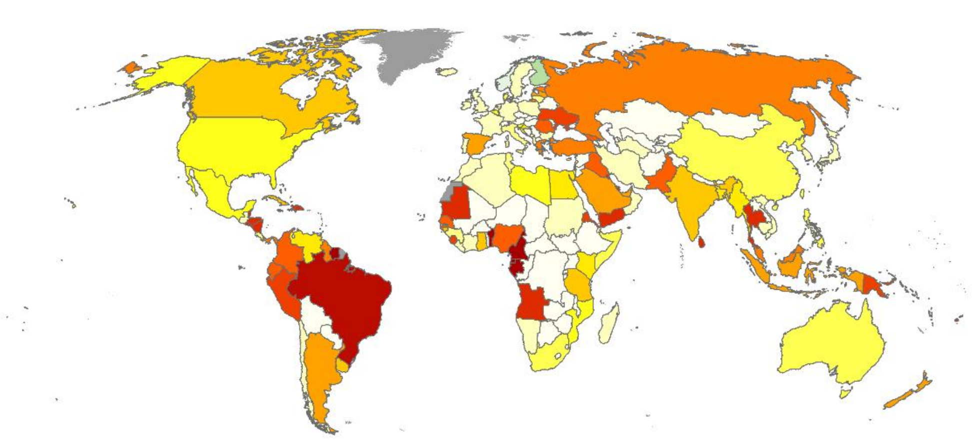
effect of sea level rise (SLR) on global tidal elevations through a set of simulations, using the global DFLOW FM set-up [32].Coastal floods at global scale are projected to affect 64 million people (+15%) in the 2050s considering the 2015 population and 72 million (+29%) under the SSP3 population (Figure 7 and Table *2*). The largest absolute population exposed is displayed in Asia with 41 million people (+16%) with no population growth and 43 million people (+21%) under SSP3. The largest percent changes in population occur in Africa (+27% with fixed population, +245% SSP3 population) and South America (54% with fixed population, 158% under SSP3 population).

a) Change in exposed population to coastal floods for the 2050s (%) – 2015 population



b) Change in exposed population to coastal floods for the 2050s (%) – SSP3 population

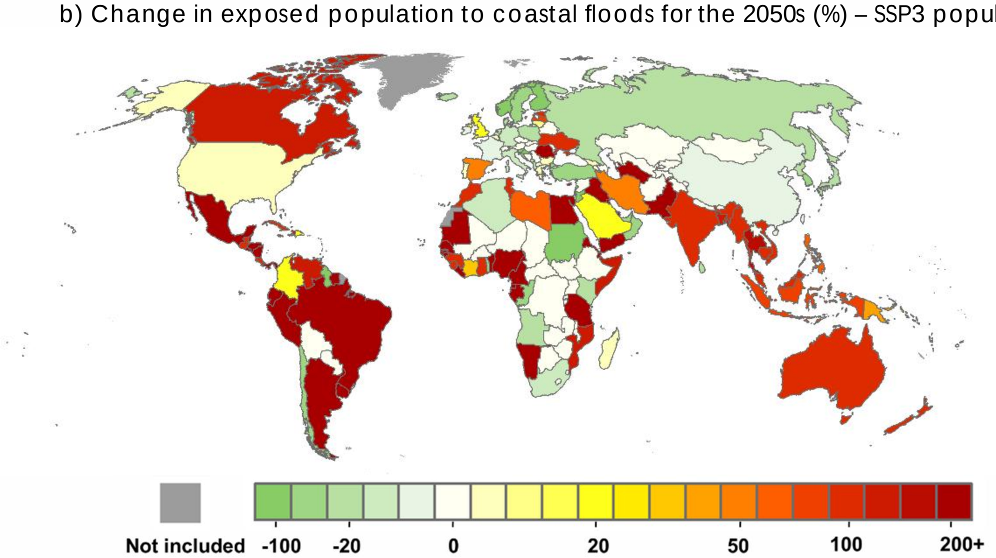


Figure 7. Same as Figure 6 but for coastal flood projections.

2.2.3 Drought Exposure

As a measure of drought, we compute the Standardized Precipitation-Evapotranspiration Index (SPEI), which is a multi-scalar drought index based on precipitation and potential

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evapotranspiration (PET)[52,53]. To Compute SPEI, we use temperature and precipitation from 21 Coupled Atmosphere Ocean Global Climate Models from the NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP) dataset[62]. NEX-GDDP is comprised of daily 0.5-degree resolution statistically downscaled climate scenarios derived from the Coupled Model Intercomparison Project Phase 5. For this analysis, PET is estimated using the Hargreaves (1994)[63] formulation modified by Droogers and Allen (2002)[64]. The occurrence of drought is considered as a 12-month event exceeding severe conditions (SPEI < -1.5).

At global scale 1.1 billion people (+169%) in 2050s are projected be exposed to severe drought considering the 2015 population and 1.5 billion (+280%) under SSP3 population (Figure 8 and Table *2*). The largest percent changes in population exposed occurs in Africa (+230% with fixed population, +500% under SSP3 population), in South America (+225% with fixed population, +325% under SSP3 population) and in North America (+238% with fixed population, +308% under SSP3 population).

Table 2. *Total population exposed [millions] and percent change in population exposed compared to the historical climate for each hazard under RCP 8.5 for both the GHSL 2015 and SSP3 population estimates in each of the major regions of the world.*

		River Floods		*Coastal Floods*		*Droughts*	
	Population	GHSL 2015	SSP3 2050	GHSL 2015	SSP3 2050	GHSL 2015	SSP3 2050
Africa	Pop	15	31.1	4.8	12.9	226.3	412.9
	%change	6.3	119.8	27.0	245.3	229.2	500.6
Asia	Pop	102.9	133.1	40.6	42.5	545.5	781.6
	%change	192.8	278.7	15.7	21.0	125.1	222.5
Europe	Pop	2.2	2.0	15.7	12.7	147.2	136.5
	%change	151.1	134.3	7.1	-13.3	232.6	208.5
North America	Pop	1.1	1.6	2.0	2.3	110.7	133.5
	%change	30.3	87.9	23.3	42.7	237.8	307.7
South America	Pop	4.5	6.0	0.8	1.4	71.5	93.4
	%change	295.4	427.0	53.3	157.6	225.1	324.4
Oceania	Pop	0.1	0.2	0.3	0.4	5.6	7.2
	%change	160.3	330.6	25.1	52.0	223.1	317.3
Global	Pop	125.9	174.1	64.2	72.2	1106.8	1565.1
	%change	141.2	233.4	14.8	29.1	168.7	280.0

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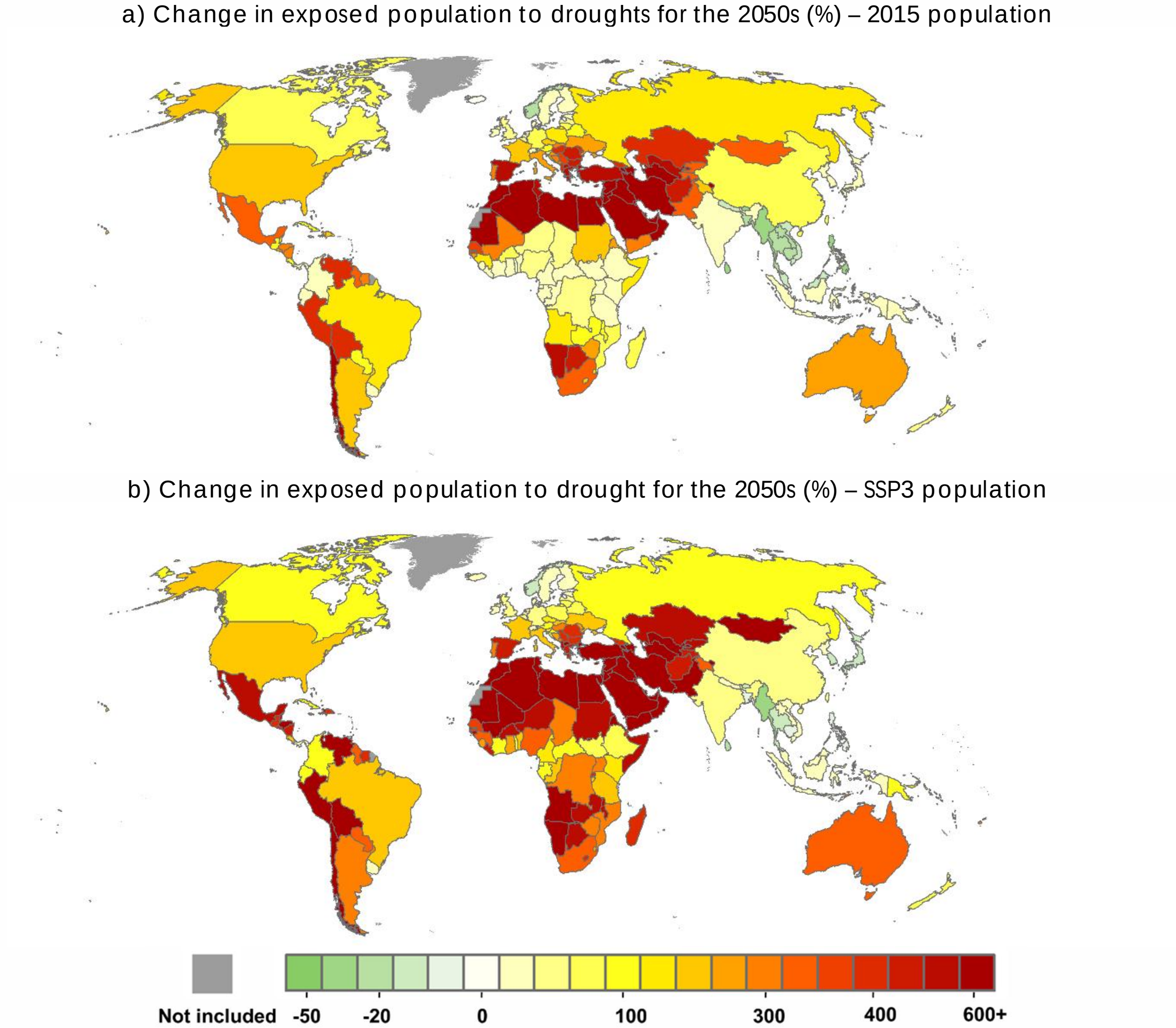

Figure 8. Same as Figure 6 but for drought occurrence.

2.2.4 Multi-hazard Classification

For this stage, exposed population to the individual river flood, coastal flood and drought hazards are normalized and combined to form the INFORM risk indices. We then further categorize the data using analogous risk classifications according to the five thresholds ranging from very low risk (5) to very high risk (1) introduced by Marin-Ferrer et al. (2017) (Table 3). The classes provide a greater ability to monitor, control and even manage risk because root causes of risk can be better identified and are more robust and less sensitive to details in calculation and definition. The classifications are performed for the historical climate with 2015 fixed (GHSL 2015) population, RCP 8.5 with 2015 fixed population, and RCP 8.5 with SSP 3 population (Table 3 and Figure 9).

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According to the results, only for a relatively small number of countries, the variations in hazard and exposure levels are projected to result in shifts in risk classes between the historical climate and the combined RCP 8.5 SSP3 scenarios: Armenia (Low to medium), Austria (very Low to Low), Belarus (Very Low to Low), Belize (Low to Medium), Burkina Faso (High to Very High), Djibouti (medium to high), Hungary (very low to low), Kazakhstan (very low to low), Kuwait (very low to low), Malawi (Medium to High), Mali (High to Very High), Namibia (Low to Medium), Poland (very low to low), Senegal (Medium to High), Uzbekistan (Low to Medium) and United States (Low to Medium) (Table 3). In all but a few cases, the shift occurs regardless if population is fixed at 2015 levels or changed to the SSP3 projection.

Table 3 Risk classifications and the number of countries each class for the historical climate and the mid-century RCP 8.5 projections under fixed and SSP population estimates.

Level	Risk Class	Countries - Historical	Countries - GHSL2015	Countries - SSP3
1	Very High	17	18	19
2	High	34	37	36
3	Medium	48	49	49
4	Low	60	62	62
5	Very Low	32	25	25

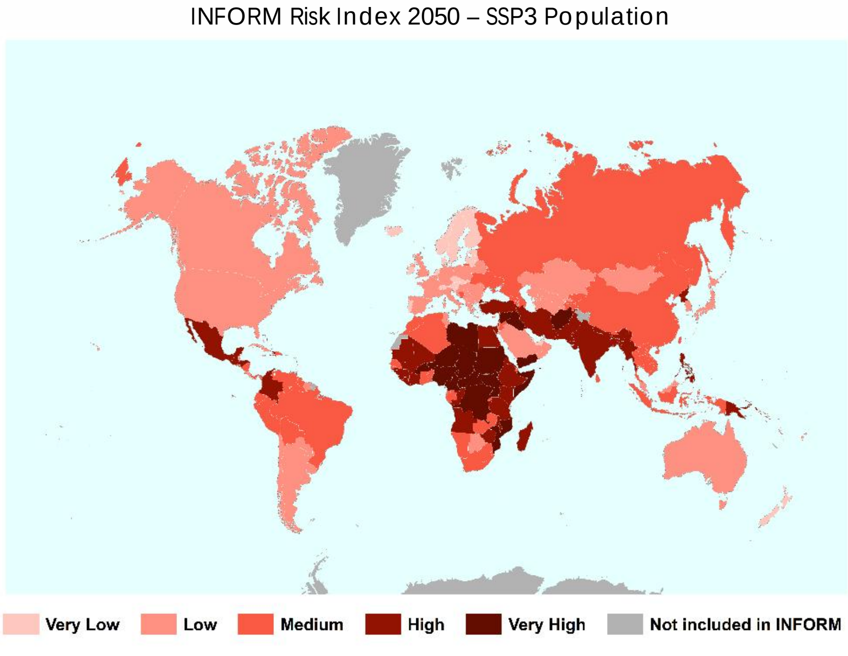

Figure 9. INFORM Risk index for the mid-21st century under RCP 8.5 and SSP3. INFORM Risk is the product of hazard and exposure, vulnerability and lack of coping capacity

2.2.5 Vulnerability / Lack of Coping Capacity

As a final step of the extended INFORM GRI analysis, we determine the change coping capacity in the mid-21st century due to climate change (RCP 8.5) and population change

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(SSP3) to return to the original level of risk associated with the historical climate and 2015 population (Figure 10). This provides an indication of the increase in vulnerability resulting from climate and population change. It is important to note that vulnerabilities not associated with climate and population change, such as uprooted people, food security and access to health systems, are considered to remain fixed between the scenarios. Under SSP3, Kuwait, Oman, Qatar and United Arab Emirates in Western Asia, Cabo Verde, Namibia, Liberia, Trinidad and Tobago, Botswana, Lesotho, Eswatini, Gambia and Mauritius in Africa, Kazakhstan, Turkmenistan and Mongolia in Asia, Czech Republic, Hungary, Poland, Austria, Slovakia, Portugal, Cyprus and Lithuania in Europe, Bahamas, Brunei in South East Asia, Australia in Oceania, Belize and Argentina in Americas require higher vulnerability reductions to maintain the current risk.

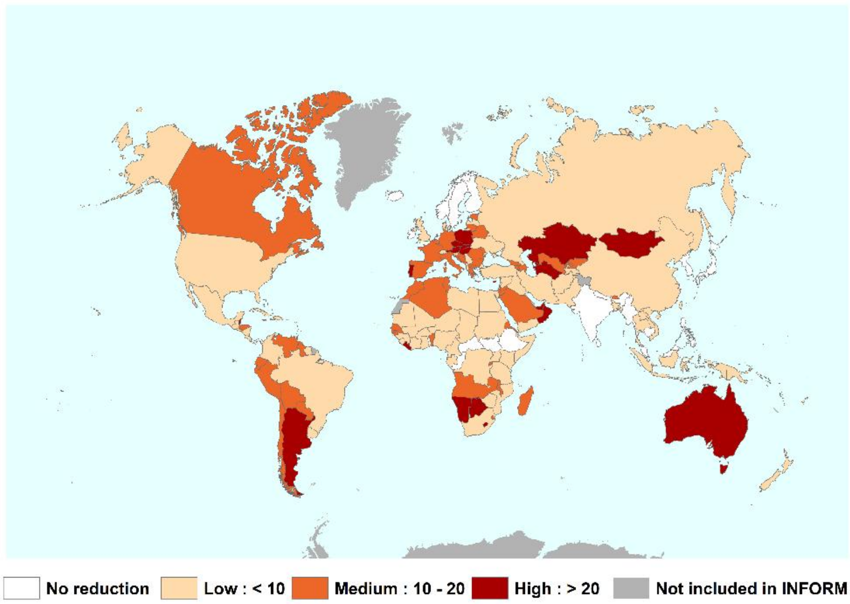

Figure 10. Change coping capacity in the 2050s due to climate change (RCP 8.5) and population change (SSP3) to return to the original level of risk associated with the historical climate and 2015 population. Risk is defined as the combination of hazard and exposure, vulnerability and lack of coping capacity.

2.2.6 Initial Hotspot Selection

In this section, we identify initial key hotspots within defined geographical domains involved in EU external action partnership areas. Figure 11 through Figure 14 and Table 4 illustrate the hazard/exposure and vulnerability levels enabling decision-makers to single out the initial hotspots exposed to river and coastal floods, droughts and combined hazards, respectively. The hazard/exposure values for river floods, coastal floods and droughts are categorized in low, medium and high categories using quantile classifications. We present the countries with

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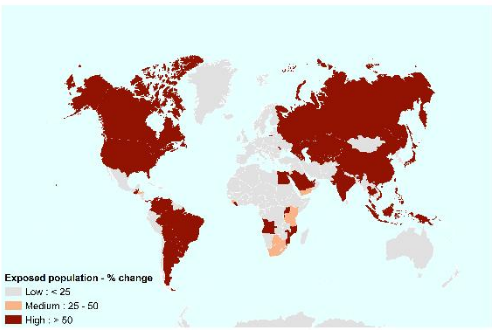
the larger changes in exposure (“high” category) and along with the vulnerability scores. In this way, we are able to explore the key hotspots in which the coupled hazard/exposure and vulnerability values are relatively high. In addition, we determine the individual vulnerability components to inform the most incompetent factor associated with each country. A full list of exposure and vulnerability values for each country can be found in Annex 1.

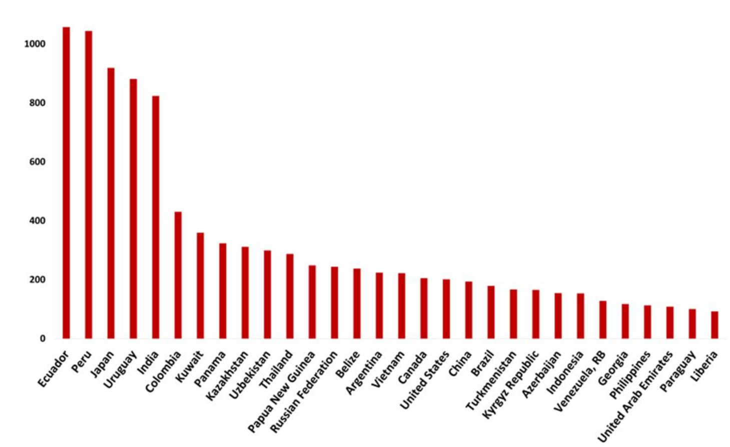
For river floods we identify Liberia, Uganda and Mozambique in Africa, Egypt, Georgia and Armenia in ENP, Ecuador, Peru, Colombia, Brazil and Venezuela in Latin America and the Caribbean, India, Uzbekistan and China in Asia, Papua New Guinea, Philippines and Vietnam in Southeast Asia and the Pacific (Figure 11).

River Floods

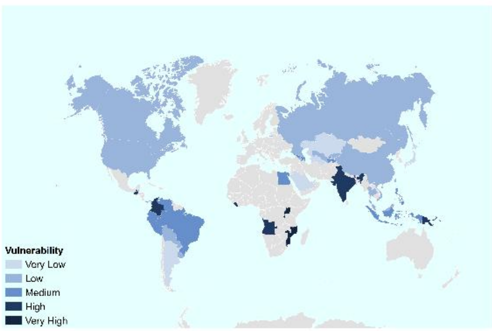
a) Change in exposed population (%)



b) Change in exposed population of the 30 partners with the highest percent change (%)



c) Vulnerability of EU partners



d) Vulnerability of the 30 partners with the highest percent change

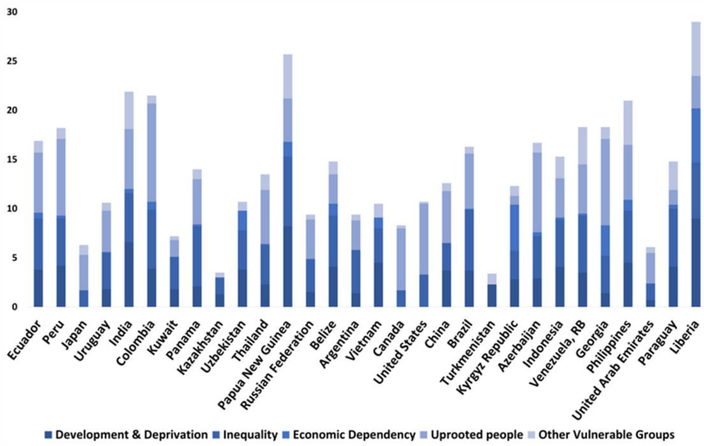


Figure 11. River flood exposure classified from low to high and vulnerability classify from very low to very high for RCP 8.5 climate change and 2015 population for EU partner countries: a) change exposed population (%); b) Change in exposed population of the 30 partners with the highest percent change (%); c) vulnerability; and d) Vulnerability of the 30 partners with the highest percent change. Vulnerability

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is comprised of five pillars namely development and deprivation, inequality, economic dependency, uprooted people and other vulnerable groups (blue shading).

For coastal floods the key hotspots are: Benin, Cameroon, Nigeria, Senegal, and Ghana in Africa, Georgia, Turkey and Ukraine in ENP, Suriname, Honduras, Haiti, Nicaragua, El Salvador and Brazil in Latin America and the Caribbean, Yemen and India and in Asia, Papua New Guinea, Fiji and Thailand in Southeast Asia and the Pacific (Figure 12).

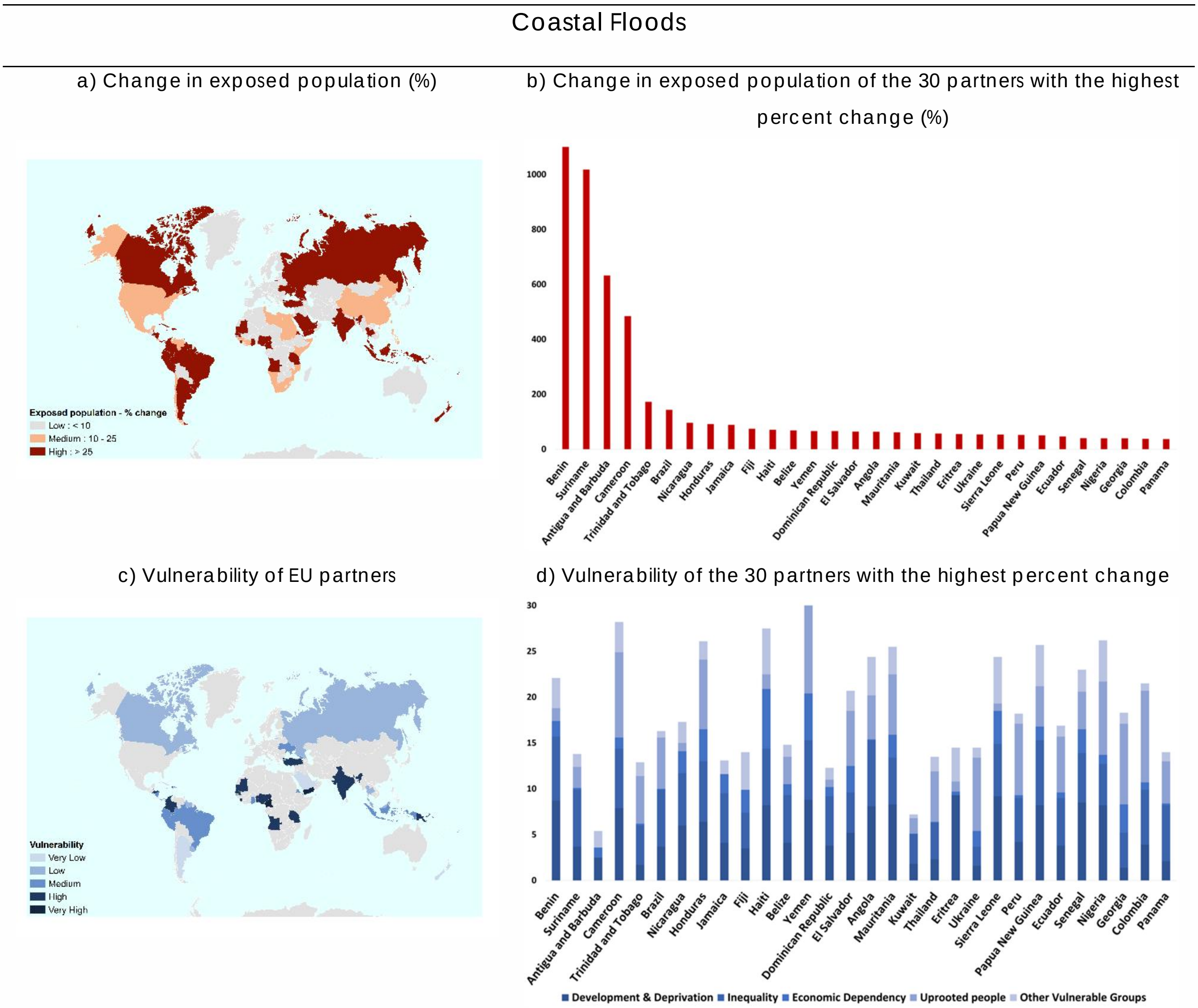

Figure 12. Same as Figure 11, but for coastal floods.

For droughts the hotspot countries are Mauritania, Namibia, Botswana, Mali, Senegal and Zimbabwe in Africa, Egypt, Jordan, Libya, Syria, Palestine, Lebanon and Morocco in ENP, Peru, Bolivia, Venezuela, Honduras, Nicaragua, Haiti and Guatemala in Latin America and the

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Caribbean, Yemen, Uzbekistan and Kyrgyzstan in Asia, Papua New Guinea and New Zealand in Southeast Asia and the Pacific (Figure 13).

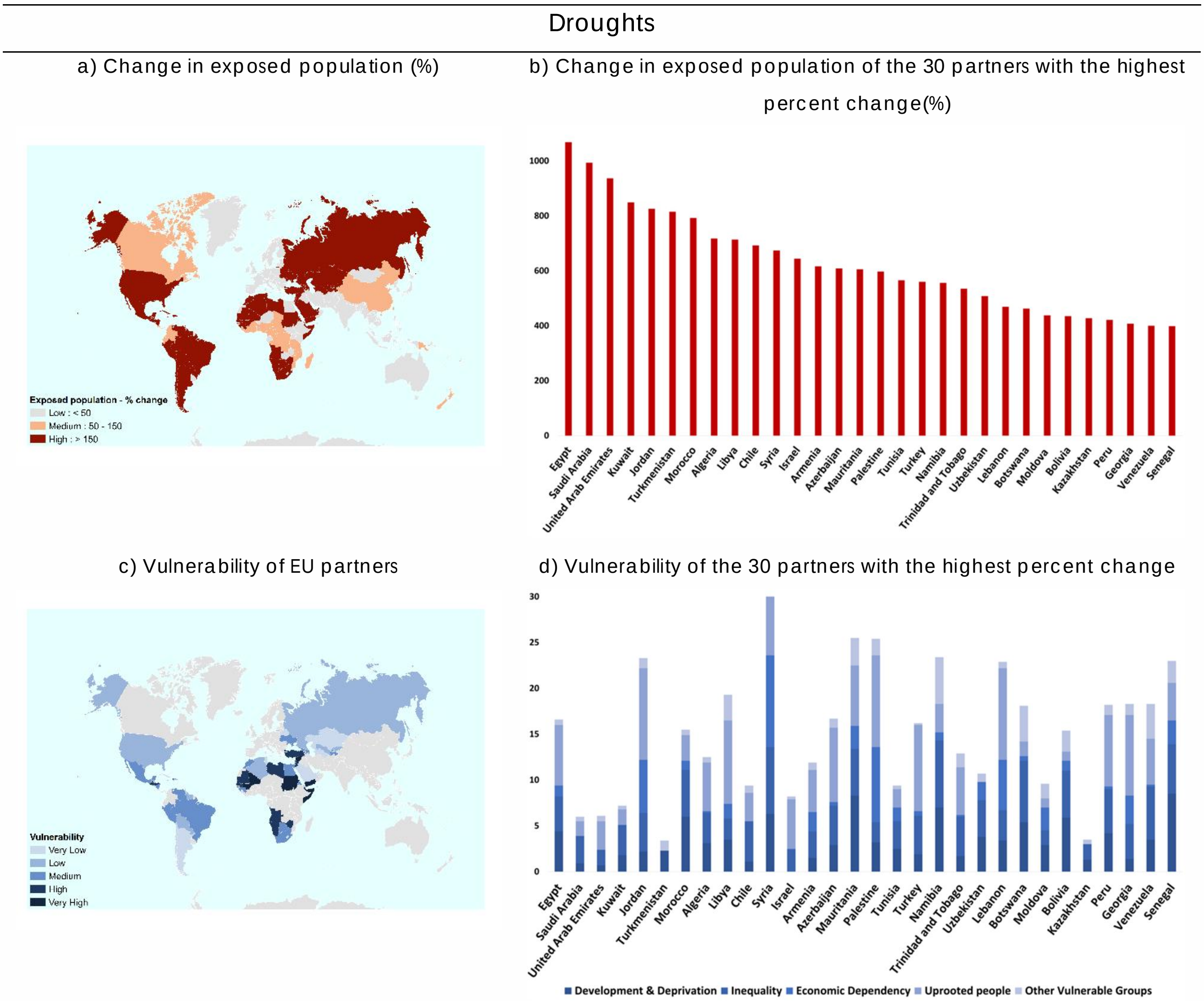

Figure 13. Same as Figure 11, but for droughts.

Finally, we determine hotspot areas for multi hazard exposure, among which the key areas are: Namibia, Botswana, Senegal, Mali and South Africa in Africa, Jordan, Egypt, Palestine, Syria, Lebanon, Libya and Azerbaijan in ENP, Yemen, Kyrgyzstan and Uzbekistan in Asia, Honduras, Haiti, El Salvador, Bolivia and Peru in Latin America, Papua New Guinea and New Zealand in Southeast Asia and the Pacific (Figure 14 and Table 4).

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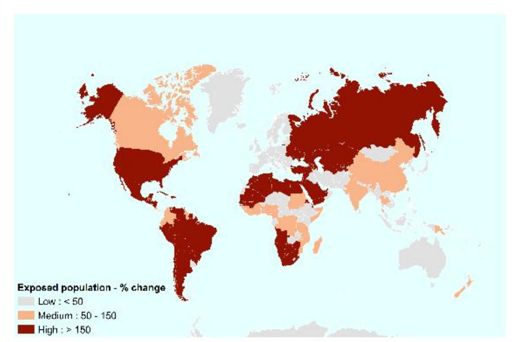
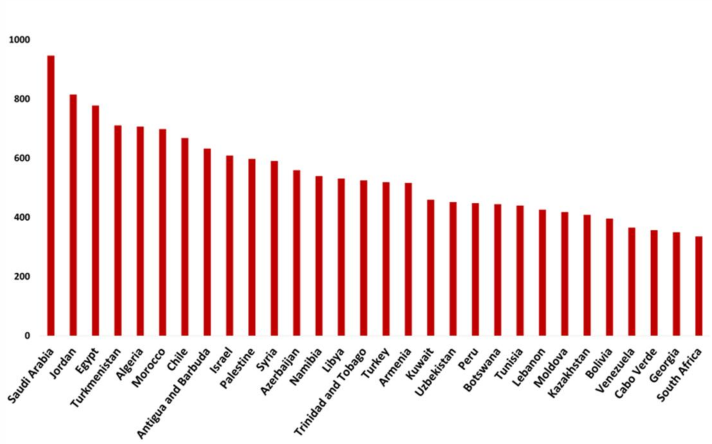
Multi Hazard

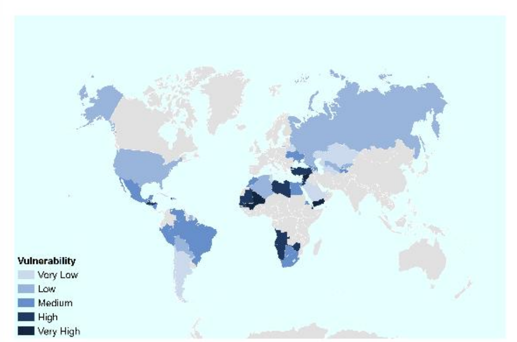
a) Change in exposed population (%)



b) Change in exposed population of the 30 partners with the highest percent change (%)



c) Vulnerability of EU partners



d) Vulnerabilityof the 30 partners with the highest percent change

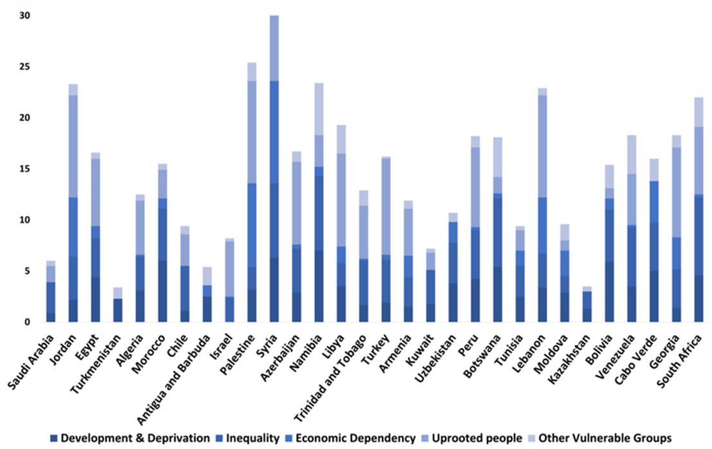


Figure 14. Same as Figure 11, but for combined multi-hazard (river flood, coastal flood and drought).

In addition to the vulnerable EU partners identified for each hazard, we also consider the following metrics based on the extended INFORM GRI to identify additional vulnerable partners:

- Currently vulnerable hotspots for which the variations in hazard and exposure levels are projected to cause shifts to high or very high-risk classes between the historical climate and RCP 8.5 with SSP3 population: Burkina Faso (high to very high), Djibouti (medium to high), Malawi (medium to high), Mali (high to very High), Senegal (medium to high) and Togo (medium to high); and

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- Currently vulnerable Hotspots that require enhanced adaptive capacity in the future to retain the current risk while exposed to amplified hazards: Namibia, Liberia, Lesotho, Eswatini and Gambia (Figure 10).

Table 4 EU partners countries with high vulnerability for river flood, coastal flood, drought, and combined multi-hazard.

	River Floods	Coastal Floods	Drought	Multi-hazard
Africa	Liberia, Uganda and Mozambique	Benin, Cameroon, Nigeria, Senegal, and Ghana	Mauritania, Namibia, Botswana, Mali, Senegal and Zimbabwe	Namibia, Botswana, Senegal, Mali and South Africa
ENP	Egypt, Georgia and Armenia	Georgia, Turkey and Ukraine	Egypt, Jordan, Libya, Syria, Palestine, Lebanon and Morocco	Jordan, Egypt, Palestine, Syria, Lebanon, Libya and Azerbaijan
Latin America and Caribbean	Ecuador, Peru, Colombia, Brazil and Venezuela	Suriname, Honduras, Haiti, Nicaragua, El Salvador and Brazil	Peru, Bolivia, Venezuela, Honduras, Nicaragua, Haiti and Guatemala	Honduras, Haiti, El Salvador, Bolivia and Peru
Asia	India, Uzbekistan and China	Yemen and India	Yemen, Uzbekistan and Kyrgyzstan	Yemen, Kyrgyzstan and Uzbekistan
Southeast Asia and Pacific	Papua New Guinea, Philippines and Vietnam	Papua New Guinea, Fiji and Thailand	Papua New Guinea, New Zealand	Papua New Guinea, New Zealand

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3 Modelling food security and displacement

3.1 Selection of hotspot regions

3.1.1 Historical context: Recent world food crises and disaster-induced internal displacement

Crop price volatility on world markets (WM) that partially translate to domestic markets is challenging for food security especially for poorer consumers in developing and emerging economies[65,66] who cannot be protected sufficiently by support programs from their local governments[67]. In just the last decade, two prominent price peaks - in 2007/08 and 2010/11 - are estimated to have pushed 63[68] to 80[69] million people and about 44 million people, respectively, into food insecurity triggering food riots especially in African countries[70] (Figure 15).

Figure 15. Sketch of the global food web. Crop failure in major bread-basket regions in combination with unilateral policy measures such as export restrictions lead to food insecurities in import dependent countries which may potentially trigger social unrest.

Price volatility results from a complex interplay of various long-term and short-term drivers whose relative importance is still a contentious topic[71]. The set of long-term drivers discussed to have contributed to the recent global food crises include population growth, changing diets in emerging economies[72], low investments in Research and Development in the 1990s[65] and, especially in the last decade, the rapidly increasing use of biofuels[73,74].

In the last four decades, weather driven yield variability has been the major short-term driver of WM price volatility[75]. For instance, nearly simultaneous droughts affecting several major

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exporting countries, i.e. multi bread-basket failures which led to the record-low stock levels have preceded both recent price peaks[76]. In this situation, national policy interventions such as export restrictions by main producers including the Ukraine and Russia[77] and government-driven restocking attempts by several import-dependent countries in the Middle East, North Africa and Asia[76] are discussed to have exacerbated the price hikes by further tightening the WM. More process-based quantitative modeling is needed to gain a deeper understanding of the market dynamics allowing for tailored food security policies[78].

Besides food security risks, we consider the risk of internal population displacement due to natural disasters. Displacement means that people leave their homes in spontaneous flight or by ordered evacuation, either after a disaster strikes or to avoid an imminent disaster. Compared to international migration, displacement of people within country borders tends to receive less public attention, but is actually greater in numbers. Since 2009, which is when reliable records begin, every year between 15 and 42 million people have been displaced due to natural disasters globally[79]. These numbers do not include people displaced due to conflicts and violence, which amount to another 3 to 12 million per year during the last decade. Importantly, many countries suffer both violent conflict and natural disasters, and each of these hazards can increase people's vulnerability to displacement by the other.

Displacement incidence is particularly high in many countries of the global South, but also frequently occurs in highly developed countries (Figure 16). Internal displacement is an enormous humanitarian problem given that many of the displaced not only lose their homes and belongings, but also income sources and access to social services, and suffer disruption of their social networks[80]. It can also present a significant challenge to peace and sustainable development in affected countries, by keeping or pushing people into poverty, disrupting communities and settlement patterns, and straining urban economies and labor markets as well as governments' fiscal and institutional capacities.

While disaster-induced displacement appears to be widespread, individual incidences are linked to weather events - mainly to floods and storms, but also wildfires, droughts, or other weather-related hazards - that are inherently unpredictable over the long run. Therefore, displacement risk should be assessed in a probabilistic rather than deterministic manner.

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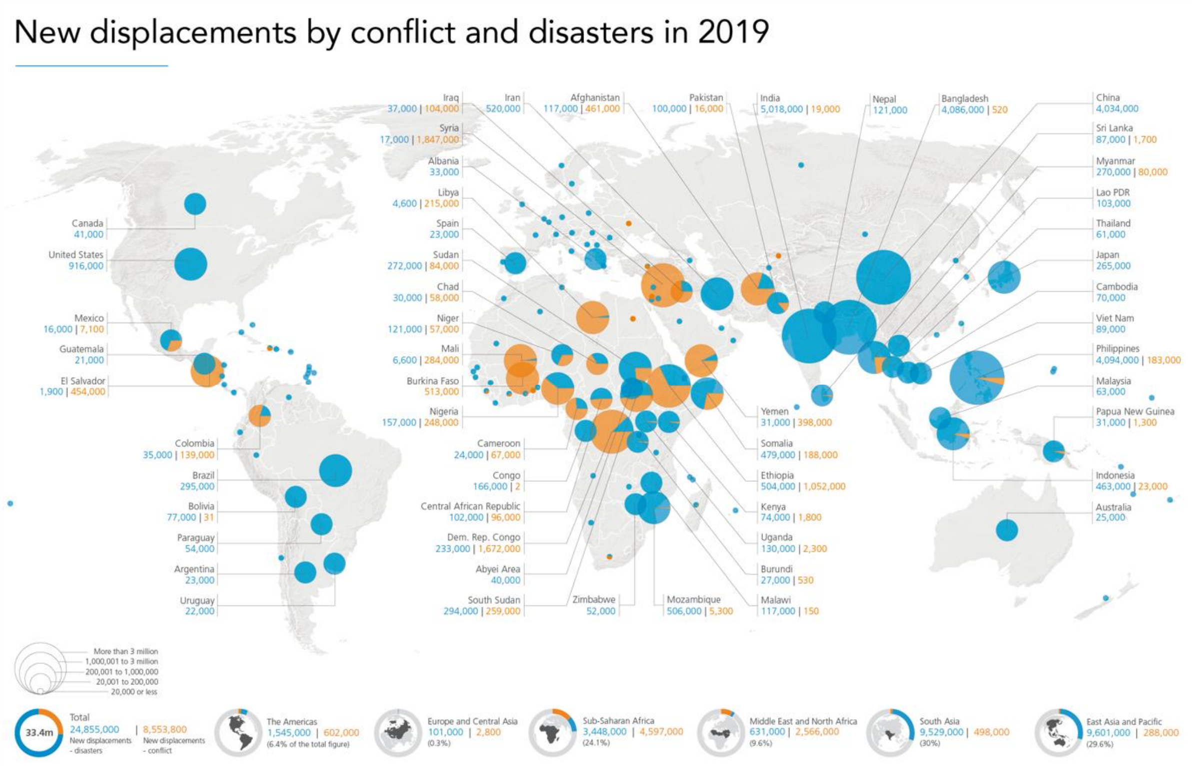

Figure 16. Overview of internal population displacement incidence in 2019. Blue segments depict disaster-induced displacement, while orange segments depict conflict-induced displacement. Courtesy Internal Displacement Monitoring Centre (IDMC) [80].

3.1.2 Food insecurities in hotspots regions

In the last decades, low-income populations in countries of Northern Africa and the Horn of Africa have been exposed to high risk of food insecurities for several reasons. First, many countries in the region have relatively high import dependencies on European countries and former Soviet Union countries for historical reasons, which renders them vulnerable to crop failures of these main exporters (Figure 17)[81–83]. For instance, Egypt is the world's largest wheat importer with strong import dependencies from Russia [84]. Second, many countries in the regions are facing volatile domestic harvests and have, at the same time, relatively small grain reserves which increased their dependency upon food imports, or even food aid in drought years. For instance, the 2019 spring drought in the Horn of Africa is among the top three driest on record, which required the EU to increase emergency humanitarian funding by €50 million for a total of €366 million since 2018. Even countries like Ethiopia, which are relatively close to self-sufficiency, are vulnerable due to relatively small reserves compared to domestic consumption. For instance, if Ethiopia had faced a modest 1-in-20-year production decline of 7% (13%) in wheat (maize) in the agricultural year 2019, it would not have been able to buffer

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it by its reserves. As another example, Kenya would not have buffered a 1-in-20-year failure of its maize harvest in the agricultural year 2019[84].

The situation differs from country to country, but a combination of these risks already renders many North African countries and countries at the Horn of Africa to food insecurity hotspots in the present climate.

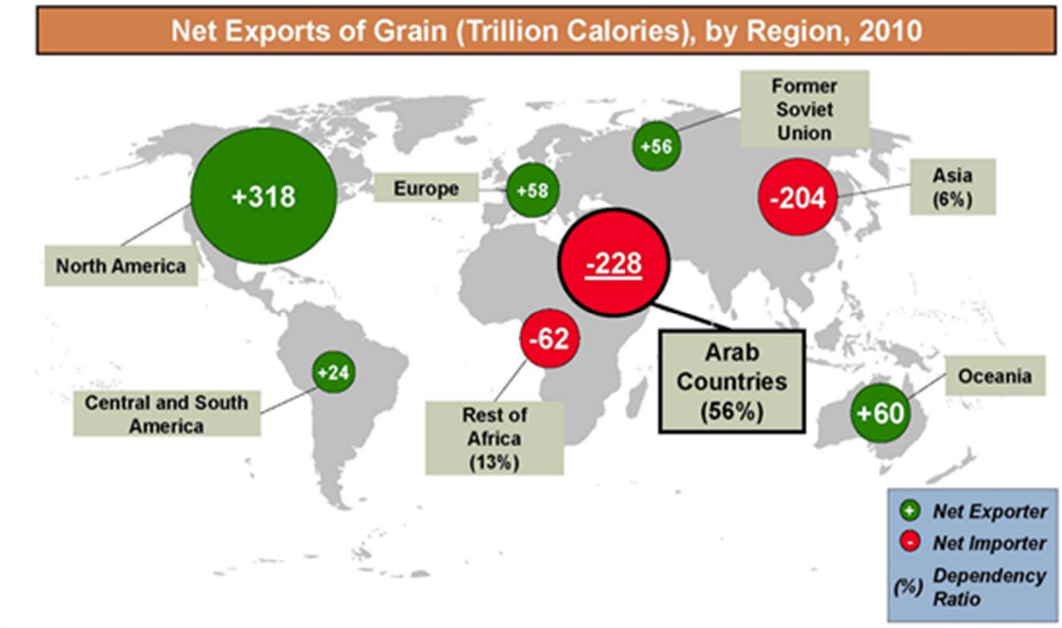

Figure 17. Trade dependencies in the global food web during the world food crises in 2010/11[85]

3.1.3 Disaster-induced displacement in hotspot regions

Countries in East Africa frequently experience high numbers of disaster-induced displacement as a result of both high vulnerability and frequent exposure to destructive weather hazards. For instance, in Ethiopia, several widespread flood events displaced about half a million people in 2019 alone. In the same year, a similar number of people were displaced in Mozambique by two successive tropical cyclones hitting the country’s long Indian Ocean coastline. North Africa has generally been less exposed to intense floods and storms in the past; however, vulnerabilities can be high, such that displacement does occur when disaster strikes. For instance, in Libya, several thousand people were displaced due to floods in 2019. At the same time, the ongoing conflict in Libya has displaced hundreds of thousands of people, who in turn may often find themselves in marginal situations more vulnerable to weather-related hazards.

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3.1.4 Future challenges induced by climate change and socioeconomic development in hotspot regions.

Future food security may be challenged in large parts of northern Africa and the Horn of Africa due to a combination of relatively large, fast growing, low-income populations with substantial increases in both drought frequency and drought severity[86]. In the absence of adequate adaptation measures, declines in crop yields are expected in those regions[87]; countries of northern Africa and the Horn of Africa are likely to remain import dependent in the decades to come[88] rendering the hotspot regions particularly vulnerable to disruptions of the global food system caused, for example, by multiple breadbasket failures[89,90]. One mechanism causing these failures may be mid-latitude circumglobal Rossby waves associated with a strongly meandering jet stream that can cause simultaneous heatwaves and floods across the northern hemisphere[91,92]. For instance, the Russian heatwave in 2010 that substantially contributed to the global food crisis 2010/2011 can be attributed to such a blocking event that caused coinciding fluvial floods in Pakistan[91,93]. There is some evidence that extreme summer weather events related to Rossby wave blocking events may become about 50% more frequent[94], however large model uncertainties remain[95].

Displacement risk in East Africa may rise in the future both due to an increase in exposure as a result of growing populations and the expansion of marginal settlements, and an increase in hazard given that both regional river flood hazard and the intensity of tropical cyclones are projected to increase due to global warming[96]. In North Africa, future challenges may come from continuing or escalating violent conflicts which increase vulnerabilities, but also from rapid urban development and expanding informal settlements that increase flood exposure, for instance, in Egypt. Alterations of the Nile river flow regime due to the operation of the new Grand Ethiopian Renaissance Dam may also affect flood hazard downstream. Finally, sea level rise in the Mediterranean and the Indian Ocean, and the associated increase in storm surge hazard, may become a growing concern for displacement risk.

3.1.5 Hotspot countries

Egypt is a prominent representative of an import dependent North African country, which could become the focus country in the region. Egypt is the most populated country of the region. Egypt is the world's top importer of wheat whose cereal import dependency ratio amounts to around 40% (FAOSTAT [84]), with a substantial portion of its population depending on imported cereals. Such a large dependence on food imports and exposure to price spikes in

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the world agricultural market have already contributed to social unrest in the past[97]. Importantly, attempts to reduce import dependency will be hindered by more and more difficult climatic conditions in the region[98], loss of agricultural land in the Nile delta due to sea level rise[99] and possible water scarcity due to regional energy projects[100].

Ethiopia is also a major country at the Horn of Africa. Being relatively close to self-sufficiency with regard to major staple crops, it has small import dependencies but also relatively little world market integration (FAOSTAT[84]). In consequence, it has not always been possible to mitigate domestic crop failures by grain purchases contributing to severe famines[101]. Already drought prone in the present day climate, drought risk is projected to increase under global warming in parts of the country (Figure 8)[102]. Both Ethiopia and Egypt are also relevant study areas for flood-induced displacement (Figure *6*).

3.2 Storylines

We will develop three storylines: two on food security and one on internal displacement. Under global warming, the severity and frequency of agricultural droughts is projected to change on a regional level (Figure 8)[98]. In the first food security storyline (FS1), we assess food insecurities in North and East Africa as well as the Horn of Africa (focus region) that arise from simultaneous severe crop failures in major exporting countries and coincide with a severe local drought in the focus region. The second food security storyline (FS2) addresses the additional impacts of potential regional increase in drought frequency on the stability of the global food web and food security in the focus region. This long-term analysis adds an important dimension to our food security analysis since one-time shocks may be buffered by stocks if inventory levels are sufficiently high, but a higher drought frequency could lead to a depletion of the stocks and persistent food insecurities in the absence of additional adaptation and mitigation strategies. The third storyline (DD1) deals with flood induced displacement in the focus region. Under climate change, in large parts of the region the likelihood of extreme flood events are projected to increase. In this region with high levels of poverty, limited availability of protective infrastructure, and high prevalence of conflict, the vulnerability to flood-induced displacement is likely high, and extreme flood events could lead to massive numbers of internally displaced people.

3.2.1 Storyline FS1: Food security implications of a multiple bread-basket failure in combination with a severe local drought.

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Hazard. On a regional level, droughts are projected to become more frequent and intense (Figure 8)[98]. This may render the combination of crop failures in major producing countries with local droughts more likely[87]. The impacts of the associated multiple breadbasket failures are likely to be felt strongest in already drought-prone, import dependent countries, with little reserves in the focus region (North and East African countries and countries at the Horn of Africa).

Historical event. We base our storyline on nearly simultaneous droughts between June 2010 and April 2011 in Russia and other major crop producing regions, which led to crop failures that fuelled the global food crisis[76,103]. This event i) had a major food security implications in the hotspot regions and ii) the Russian heatwave, likely one of the main climatic driver of the food crisis, was caused by a Rossby wave blocking event[91,93] that could potentially be attributed to anthropogenic climate change[104]. This event during the 2010-2011 agricultural year is a prototypical example of multiple breadbasket failures that had, amplified by unilateral policy measures such as export restrictions, severe impacts on food security in the focus region.

Counterfactual “worst case” hazard scenario. We consider the regional food security implications of a counterfactual, yet plausible, “worst case” situation (in the present-day climate) where a severe multiple breadbasket failure coincides with a severe local drought. We then assess how the resulting supply shortages translate into food insecurities in import dependent countries in the focus regions.

Future projections: scaling of “worst case” counterfactual with global warming. We scale the individual events according to their changes in severity under global warming under two different warming scenarios: i) a strong mitigation climate scenario (Representative Concentration Pathway (RCP) 2.6) likely to limit the warming to less than 1.5℃ above preindustrial levels in compliance with the Paris Agreement, and ii) a more business-as-usual scenario (RCP 6.0) resulting in higher warming levels (e.g. instead of taking rare - say once-in-a-hundred year - event in the present climate, we choose once-in-a-hundred year events in +2 and +3℃ warmer worlds) (see paragraph *input data* the Methodological framework subsection for details). We then assess the food security implications of these counterfactual events in the present-day socioeconomic setting in order to identify vulnerabilities and adaptation needs accounting for uncertainties in crop yield projections.

3.2.2 Storyline FS2: Food security implications of recurrent multiple bread-basket failures and local droughts

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Starting from the same hazard scenario and same historical calibration as storyline FS1, we study the food security implications of recurrent crop failures in major cropping regions in combination with local crop failures in the focus region (North and East Africa and Horn of Africa). Since it often takes years for global stock levels to recover from severe crop failures in main producing regions, changes in drought severity and frequency in these regions may have severe implications for global food web stability[83].

We assess the regional food security implications induced by changes in the severity and frequency of agricultural droughts until the end of the century under i) a strong climate mitigation scenario (RCP2.6) and ii) a more business-as-usual emission scenario (RCP6.0) (see Methodological framework subsection). We then compare the resulting changes in national vulnerabilities as well as national adaptation needs that arise under both mitigation scenarios.

3.2.3 Storyline DD1: Displacement induced by extreme flooding

Global warming has already altered the risk of fluvial floods[105] flooding and will continue to do so as the climate warms further[106]. In many regions, including large parts of East Africa, the likelihood of unprecedented extreme flood events is projected to rise substantially as a result[107]. This means that there is a non-negligible risk of such events occurring today. In a region ridden by conflicts and low levels of human development, vulnerability to flood-induced displacement is likely high, and extreme flood events could cause massive displacement. This would add to the burden of conflict-induced displacement and would probably require substantial foreign humanitarian assistance as local government response capacities are strained. INFORM Risk Index takes into account the uprooted people (refugees, returned refugees and internally displaced persons) as one of the main components of vulnerability (Figures 3-b, 11-14). In addition, *conflict intensity* and *Projected risk of conflict indicators* are embedded under human-induced hazard to assess the risk[37].

We will quantify the displacement risk, in terms of the expected number of internally displaced people resulting from a plausible extreme flood event, or a series of events, in the region. To this end, we will develop a displacement vulnerability function that takes into account regional conditions and thus goes beyond existing simplistic approaches that are based on a universal flood depth threshold[96,108]. We will then use an ensemble of state-of-the-art climate models and river models to generate an artificial set of plausible flood events in the region under current and future climate conditions. A particularly concerning case would be the occurrence of multiple extreme floods in close temporal proximity in the same region.

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3.2.4 Impacts on Europe: need for resilience-building in a partner country

The Northern and Eastern Africa as well as the Horn of Africa are regions prone to social unrest or local conflicts such as the ongoing (low intensity) war in Libya and the ethnical conflict in Ethiopia. These might be further fuelled by regional climate change impacts such as on drought and fluvial flood risk. For instance, food riots have revealed the link between food insecurities and social unrest in the region[109], and there is an ongoing conflict between Egypt and Ethiopia, two main players in the region, over the use of Nile River water. At the same time, Europe has strong historical ties to many countries in the hotspot regions which are, for example, express in long-standing trade relations. These are not always balanced, and several Northern African countries (e.g. Tunisia or Morocco) are strongly dependent on the import of staple crops from Europe. Political stability and socioeconomic development in the hotspot regions are of strategic importance for Europe. For instance, from the perspective of global systemic risks, Egypt plays a particularly critical role as the administrator of the Suez Canal[110].

Strong cooperation between Europe and the focus region already exist with regard to bi- and multilateral development cooperation such as the Marshall Plan with Africa [link] which comprise joint efforts to develop National Determined Contributions with mitigation and adaptation strategies to cope with climate change impacts at the national level. Moreover, the EU's relations with Africa are a key priority for the new European Commission[111] enhancing state and societal resilience in regions to the East and to South from the EU, including Middle East which is a key priority of the European External Action Service[112].

3.2.5 Methodological framework

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3.2.5.1 Modelling of food insecurities induced by trade dependencies and local crop failures

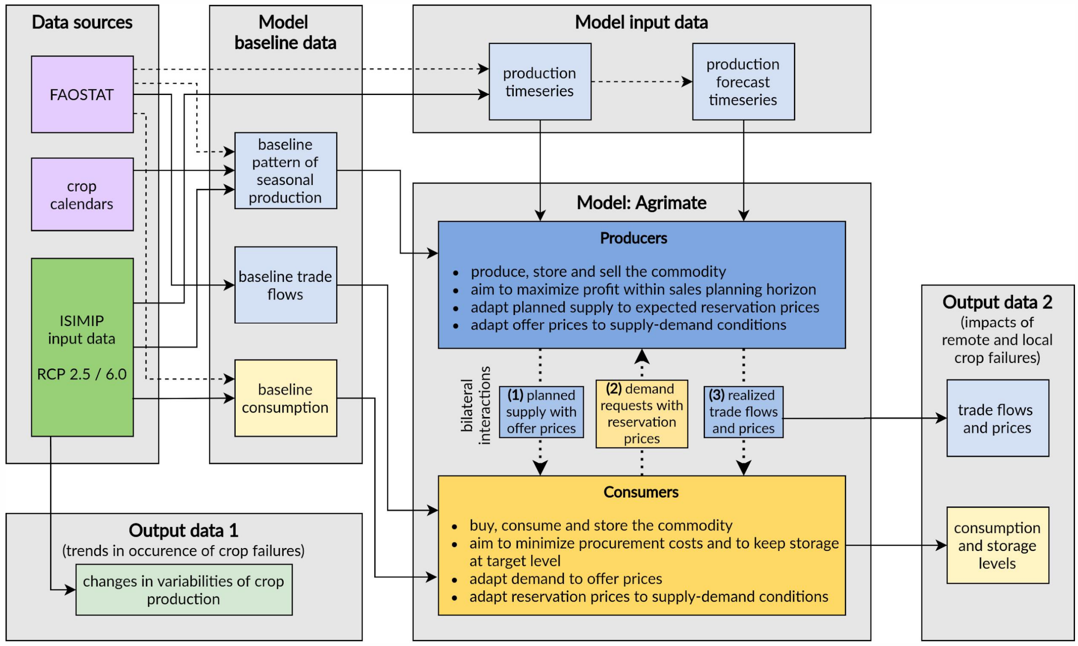

Figure 18. Schematic of the methodological framework for the food security storylines.

Model requirements: We aim to model the implications of multiple breadbasket failures as well as local drought related harvest failures for global food security with a focus on regional food security in the hotspot regions. This requires a modelling approach able to capture both the availability and access to food[113]. Hence, we need to describe the dynamics of both the variation of physical trade flows of the main staple crops and storage levels at the national level (proxy for food availability), as well as of the volatility of world market prices and its translation to national consumer prices (proxy for food security).

Agent-based agricultural market model Agrimate: Based on our experience with the global supply chain model Acclimate[114], we develop an agent-based network model, Agrimate, that describes the propagation of supply shocks in the global trade networks for individual staple crops, especially wheat, rice, maize and soybeans. Critical for capturing the combined food security implications of consecutive as well as compound crop failures in the same agricultural year (e.g. multiple breadbasket failures), Agrimate accounts for the seasonality of production and trade patterns. It allows for the modelling of the effects of unilateral trade policies such as export restrictions that can exacerbate the global food security implications of harvest failures in main exporting countries as well as the mitigation effects of national commercial and public

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inventories. In contrast to widely employed computational general equilibrium models and climate integrated assessment models, Agrimate can resolve non-equilibrium situations such as regional supply-demand mismatches with high temporal resolution (weeks). This is critical to describe supply chain disruptions in the aftermath of severe harvest failures and in the implementation of export restrictions. It is therefore designed to well complement established agricultural market models such as GLOBIOM[1] (cf. analyses in WP3) by explicitly resolving short-term supply failures. Agrimate resolves bilateral trade between countries generating a spatial dependence of crop prices; price formation is a result of a bargaining process between country level commercial storage holders trading the national harvest and national consumers that can take strategic decisions on public storage. Commercial storage holders are modelled as pure profit-maximisers weighting possible future revenues when storing grains and selling them later with the additional costs of storage. In contrast, consumer preferences respect historical trade patterns and normative decisions on the optimal stock-to-use level, i.e. the additional costs the society is willing to accept for additional food security.

Data requirements. The Agrimate model needs initialization and input data. The initialization data are baseline production, baseline consumption and baseline trade flows; and the input data are the actual national timeseries of national production and national final demand, combined with information on unilateral trade restrictions that are used to drive the model.

Model initialization. For model initialization, we use historical data on agricultural production, consumption and trade from the FAOSTAT database[84] that we combine with information on local crop calendars. Input data. For the assessment of the historical World Food Crises in 2010/11, we drive the model with FAOSTAT data on production, exports and national domestic consumption. For the counterfactual scenario in FS1 combining multiple breadbasket failures with a local drought in North and East Africa and at the Horn of Africa, a regional severe negative production anomaly is derived from FAOSTAT production data for an extended historical period.

For the scaling of the “worst case” scenario of FS1 with global warming, we will i) refer to Mann et al. (2018)[94] for the scaling of the major breadbasket failure and ii) to the multi-model yield simulations from the crop model ensemble participating at the Inter-Sectoral-Model-Intercomparison (ISIMIP) project rounds 2 and 3[115] for the scaling of the local droughts. More specifically, we calculate future timeseries of national production anomalies until 2100 under i) strong climate mitigation (RCP2.6), roughly in compliance with Paris Agreement, and ii) a more business-as-usual emission scenario (RCP6.0) assuming socioeconomic conditions to remain constant (e.g. same land use patterns as for historical drought). We then derive the

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resulting changes in the intensity of severe national production failures from the distributions of national production failures.

For the future simulations in FS2, we drive the model directly with the timeseries of national anomalies. We will employ metrics that address the availability and access dimensions of food security. such as impaired supply, critically low national stock-to-use ratios, high food price volatility, and reductions in food consumption.

3.2.5.2 Modelling of disaster-induced displacement risk

We will model flood hazard using a chain of multi-model ensembles, partly drawing on the ISIMIP simulation ensembles. Multiple global climate models will be used to drive a set of multiple hydrological models to estimate changes in runoff under climate change. The resulting changes in river discharge and river flood extent and depth will then be derived using a state-of-the-art global river and floodplain model, CaMa-Flood[116]. While the climate and hydrological models have extensively been applied and tested, the application of the river flood model to estimate displacement risk is new, and an extensive model evaluation study is currently being conducted for this purpose.

The estimated flood hazard will then be combined with current and projected future population distributions. Future population projections under the SSPs are available at a spatial resolution comparable to that of the flood model[56,117] and allow us to explore the influence of various socio-economic assumptions on the projected displacement risk and to gauge the relative importance of climatic versus socio-economic changes in driving this risk. Finally, to derive displacement risk for a given case of hazard and exposure, we develop, for the first time, an empirical displacement vulnerability function that takes into account regional characteristics related, for example, to economic and human development and protection standards. The empirical basis for this vulnerability function is taken from the two major observational records of flood-induced displacement: the Internal Displacement Monitoring Centre and the Dartmouth Flood Observatory.

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5 Annexes

5.1 Annex I - The RECEIPT WP5 Workshop on climate risks within the context of European external actions, international cooperation and development

The RECEIPT WP5 Workshop focused on two main areas, development and humanitarian aid outside of Europe.

5.1.1 Development

In developing the storylines, there is a need to define what it is meant by development, and what is essential and nonessential. The European Union is one of the main providers of international aid for climate adaptation and resilience especially in Africa. It is important to develop the storylines with an important focus on European resilience to external shocks from climate change. In exploring the spill over effects of remote risks on the EU, there is a need to link climate risk outside of Europe and development policy. Support should be provided to those most vulnerable outsides of Europe using a principled approach by the EU member states. Emphasis should be on EU budgetary aid to low income countries and how to measure success. The effects of debt relief and moving away from budgetary support to more technical support/infrastructure on adaptation could be explored. The principle of providing targeted aid to higher stability countries acting as barrier or buffer to prevent crises in lower stability countries could be considered. The reinforcement of external regional integration could benefit the EU, such as free trade between African countries buffering the impacts of a drought in one country, could be investigated. The measure of success should be the final performance of the humanitarian aid on the EU side. An important metric could be inequality. Storylines should explore multiple pathways or sub-storylines that consider different possible outcomes following diverse climate settings, principles, and/or policies. These sub-storylines should include scenarios associated with the best and worst possible outcomes. Careful consideration should be applied to define the limits of risk. Compound crises or multiple failures, such as a big hurricane occurring at the same time as a pandemic, should also be explored. How to approach climate change winners and losers as well as how to turn win-lose scenarios into win-win scenarios should be considered.

5.1.2 Hotspot areas for Development

Focus on West Africa and the MENA countries for food securities and internal displacement triggered by climate extremes, and to look at the ENP partners, and how they are prepared for adaptation to climate

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change. Participants expressed a general agreement about the initial hotspots identified by the WP5. The EU is investing in greater strategies of adaptation in Africa, is exchanging with the Mediterranean regions (North Africa), and with Eastern and Western Balkan countries. The EU is adopting a harmonised and coordinated approach for climate change adaptation, but it is crucial to foster the collaboration and cooperation between the initial hotspots' areas. Important is to better communicate within EU and the Africa, MENA and ENP states. On the other side, the approach might focus on multiple hotspot approaches, rather than an individual one, to establish mutual learning. Similar works are underpinned by the WB, UNDP, and the EU Commission. A more simple and basic approach can be explored. The EU could value, potential budget dimension, economic criteria, outbreak approach criteria.

5.1.3 Humanitarian aid

A wide spectrum of priorities and gaps regarding both the objective of the projects and the design of the storylines were explored. With regards to priorities, food security, supply chains and migration issues would be the most important elements that can affect Europe both in short- and long-term time spans. A great interest in incorporating compound and complex hazards, physical ecological systems, impacts and risk into storyline designs for risk management emerged. Another priority/gap, will be to design storylines that embrace the long-term impacts on the processes and system from the short-term disruptions and abrupt shocks. For instance, the hurricanes impact on supply changes in short term which may involve long term impacts as well, or Implications for humanitarian aid at seasonal time scale and the impacts on long term shifts in risk. Another priority/gap concerned the way the climate models are credited and incorporated into the storylines and their credibility. It was advised to develop storylines that are not correlated with climate models. As an example, there are some areas in Africa that the observational trends are against the results provided by climate models, so one storyline could be the possibility that all climate models are wrong. For instance, Copernicus Climate Services can be used at global scale. It has been reported the IPCC, which provides assessments on environment and climate change, will launch a summery for policy makers considering the environment-climate-health nexus which can be incorporated into RECEIPT. In the context of climate change, it was reported that the PESETA series for Europe may be extended at regional and global versions which could be great input into RECEIPT.

5.1.4 Hotspot areas for Humanitarian aid

The participants of the Workshop all agree on the initial hotspots identified by the WP5. However, they came up with additional hotspots. With regards to migration, Bangladesh was mentioned as one of the most important hotspots. Bangladesh suffers most from sea level rise and impacts may ignite internal and external migration. With regards to agricultural products and agroindustry, South East Asia was mentioned as one of the main hotspots where climate change may impact the trade of several agricultural products such as soya beans and palm oil to Europe. Latin America should be considered. Accordingly, wildfires linked to deforestation impact the economy and agroindustry in Latin America and

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the indirect impact on Europe could be interesting to explore. The participants mentioned the 2010 food security crisis by heatwaves from Russia and advised to add such remote aspects into storylines. Another hotspot area suggested is the Eastern Mediterranean countries where the climate change may impact food security and induce to a migration flow.

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5.2 Annex II – Extended INFORM GRI exposure and vulnerability values for each climate-related hazard

Table 5. Extended INFORM GRI mid-century climate change exposure with fixed population (2015 pop) and SSP3 2050 population (2050 Pop) and vulnerability for each EU partner country. The numbers for each hazard are ordered from the largest to smallest projected exposure using the fixed 2015 population. 1 is the lowest vulnerability and 10 is highest.

	River Flood				Coastal Flood				Drought				Multi Hazard		
Country Code	Exposure 2015 Pop (% Change)	Exposure 2050 Pop (% Change)	Vulnerability 2020 (1-10)	Country Code	Exposure 2015 Pop (% Change)	Exposure 2050 Pop (% Change)	Vulnerability 2020 (1-10)	Country Code	Exposure 2015 Pop (% Change)	Exposure 2050 Pop (% Change)	Vulnerability 2020 (1-10)	Country Code	Exposure 2015 Pop (% Change)	Exposure 2050 Pop (% Change)	Vulnerability 2020 (1-10)
ECU	1058	1575	3.8	BEN	1119	2670	4.8	EGY	1068	1701	3.9	SAU	947	1980	1.2
PER	1044	1418	4.5	SUR	1018	534	2.7	SAU	994	2077	1.2	JOR	815	1693	6.1
JPN	919	625	1.5	ATG	633	430	1.5	ARE	937	5359	1.4	EGY	778	1297	3.9
URY	881	808	2.3	CMR	485	1124	6.7	KWT	849	2288	1.4	TKM	711	1083	1.1
IND	824	1275	4.9	TTO	173	57	2.8	JOR	826	1715	6.1	DZA	707	1096	2.9
COL	430	694	6.1	BRA	143	416	3.5	TKM	815	1224	1.1	MAR	698	1118	3.3
KWT	359	377	1.4	NIC	96	265	3.5	MAR	792	1263	3.3	CHL	668	873	1.9
PAN	323	464	2.8	HND	92	1038	5.6	DZA	717	1111	2.9	ATG	633	430	1.5
KAZ	312	407	0.7	JAM	89	64	2.5	LBY	714	1896	5.2	ISR	609	1257	2.1
UZB	299	407	2.1	FJI	75	9	2.9	CHL	692	905	1.9	PSE	598	1128	6.4
THA	288	332	3	HTI	71	127	5.7	SYR	674	1618	7.7	SYR	591	1432	7.7
PNG	249	506	5.5	BLZ	69	160	3	ISR	644	1335	2.1	AZE	559	754	4.3
RUS	244	221	2	YEM	66	268	8	ARM	617	633	2.5	NAM	540	802	4.9
BLZ	238	667	3	DOM	66	20	2.4	AZE	609	824	4.3	LBY	531	1408	5.2
ARG	224	300	1.9	SLV	64	341	4.4	MRT	606	1054	5.6	TTO	525	578	2.8
VNM	222	274	2.2	AGO	64	-31	5.2	PSE	598	1127	6.4	TUR	519	815	4.9
CAN	205	217	2.3	MRT	61	1237	5.6	TUN	566	868	1.8	ARM	517	531	2.5
USA	201	208	2.9	KWT	59	586	1.4	TUR	560	884	4.9	KWT	460	1361	1.4
CHN	194	177	3	THA	57	142	3	NAM	556	824	4.9	UZB	452	625	2.1

River Flood				Coastal Flood				Drought				Multi Hazard			
Country Code	Exposure 2015 Pop (% Change)	Exposure 2050 Pop (% Change)	Vulnerability 2020 (1-10)	Country Code	Exposure 2015 Pop (% Change)	Exposure 2050 Pop (% Change)	Vulnerability 2020 (1-10)	Country Code	Exposure 2015 Pop (% Change)	Exposure 2050 Pop (% Change)	Vulnerability 2020 (1-10)	Country Code	Exposure 2015 Pop (% Change)	Exposure 2050 Pop (% Change)	Vulnerability 2020 (1-10)
BRA	179	226	3.5	ERI	56	2889	4.7	TTO	535	592	2.8	PER	448	647	4.5
TKM	167	290	1.1	UKR	54	63	3.9	UZB	508	706	2.1	BWA	445	495	3.7
KGZ	166	272	2.2	SLE	54	66	5.3	LBN	469	570	6.2	TUN	440	688	1.8
AZE	155	180	4.3	PER	52	609	4.5	BWA	463	515	3.7	LBN	426	508	6.2
IDN	153	190	3.3	PNG	51	28	5.5	MDA	438	267	1.9	MDA	418	253	1.9
VEN	128	228	3.9	ECU	47	352	3.8	BOL	435	824	3.2	KAZ	409	525	0.7
GEO	117	116	4.6	SEN	40	279	5	KAZ	428	548	0.7	BOL	396	757	3.2
PHL	113	243	4.5	NGA	40	441	6.1	PER	421	611	4.5	VEN	366	636	3.9
ARE	109	233	1.4	GEO	40	10	4.6	GEO	408	427	4.6	CPV	357	482	3.1
PRY	100	239	2.9	COL	38	20	6.1	VEN	400	690	3.9	GEO	350	364	4.6
LBR	93	366	6.1	PAN	37	671	2.8	SEN	398	1176	5	ZAF	336	378	4.7
MDA	90	24	1.9	TUR	34	-60	4.9	GUY	391	1708	3.1	MRT	329	658	5.6
BOL	84	218	3.2	MYS	34	96	3.1	CPV	357	482	3.1	MEX	313	501	3.9
UGA	82	423	7	GUY	33	-86	3.1	TJK	350	485	3.5	KGZ	294	462	2.2
SAU	81	235	1.2	RUS	33	-26	2	MEX	339	537	3.9	YEM	283	949	8
MYS	72	170	3.1	IDN	32	55	3.3	ZAF	337	380	4.7	ARE	277	1406	1.4
MOZ	68	179	7.2	ARE	32	-64	1.4	KGZ	331	517	2.2	TJK	265	375	3.5
ARM	67	68	2.5	NZL	31	64	1	YEM	317	1045	8	UKR	262	212	3.9
TJK	65	118	3.5	ARG	29	290	1.9	MLI	298	856	6.4	SEN	262	827	5
AGO	61	225	5.2	SAU	28	21	1.2	HND	292	622	5.6	SLV	262	413	4.4
BDI	58	121	6.5	GHA	27	72	4.2	SUR	291	416	2.7	HND	252	552	5.6
EGY	58	132	3.9	TZA	27	698	5.7	NIC	288	500	3.5	NIC	246	436	3.5
GTM	55	207	5.6	CAN	27	105	2.3	UKR	284	230	3.9	DOM	243	407	2.4
YEM	50	290	8	CUB	26	65	1.3	SLV	282	435	4.4	DJI	229	426	6.3

River Flood				Coastal Flood				Drought				Multi Hazard			
Country Code	Exposure 2015 Pop (% Change)	Exposure 2050 Pop (% Change)	Vulnerability 2020 (1-10)	Country Code	Exposure 2015 Pop (% Change)	Exposure 2050 Pop (% Change)	Vulnerability 2020 (1-10)	Country Code	Exposure 2015 Pop (% Change)	Exposure 2050 Pop (% Change)	Vulnerability 2020 (1-10)	Country Code	Exposure 2015 Pop (% Change)	Exposure 2050 Pop (% Change)	Vulnerability 2020 (1-10)
SLE	48	189	5.3	URY	25	233	2.3	HTI	265	545	5.7	HTI	229	474	5.7
KEN	45	198	6	IND	25	56	4.9	ZWE	258	307	5.9	ARG	222	292	1.9
ZAF	40	55	4.7	KEN	25	-49	6	ERI	257	691	4.7	USA	204	205	2.9
BWA	33	41	3.7	VEN	24	115	3.9	DOM	247	414	2.4	ZWE	201	242	5.9
TZA	32	192	5.7	EGY	23	257	3.9	DJI	231	414	6.3	RUS	192	172	2
HND	27	134	5.6	VUT	22	-72	3.7	ARG	226	291	1.9	BRA	181	230	3.5
ISR	26	136	2.1	LBY	22	47	5.2	USA	216	218	2.9	AGO	180	623	5.2
SDN	22	126	6.9	USA	21	9	2.9	SDN	213	513	6.9	SUR	175	262	2.7
BEN	19	98	4.8	MOZ	21	129	7.2	GIN	204	372	4.5	PRY	174	350	2.9
MEX	17	60	3.9	SLB	21	-29	4.1	SOM	198	542	9.3	BLZ	169	517	3
NZL	15	6	1	MEX	20	216	3.9	RUS	193	175	2	MLI	164	534	6.4
DOM	14	66	2.4	ZAF	20	-7	4.7	BLZ	187	591	3	CUB	164	151	1.3
CHL	14	38	1.9	SOM	18	127	9.3	AGO	182	632	5.2	BLR	163	131	1.3
SOM	13	114	9.3	PHL	17	47	4.5	BHS	181	112	2.3	GTM	152	398	5.6
MDG	12	140	5.1	CHN	17	-5	3	BRA	181	228	3.5	ERI	151	477	4.7
HTI	10	53	5.7	GIN	17	89	4.5	PRY	179	358	2.9	JAM	148	240	2.5
TUR	10	50	4.9	CRI	17	58	3.4	CUB	171	155	1.3	MUS	141	218	1.4
NGA	8	158	6.1	TUN	16	85	1.8	BLR	167	136	1.3	CRI	137	245	3.4
SLV	7	50	4.4	ISR	15	-50	2.1	GTM	160	412	5.6	GIN	133	262	4.5
COD	7	128	7.8	NAM	15	823	4.9	JAM	153	255	2.5	MWI	130	519	6.1
CUB	6	-7	1.3	CHL	14	-55	1.9	MWI	147	566	6.1	RWA	129	399	6.1
ETH	5	96	6.5	SDN	13	-94	6.9	CRI	142	252	3.4	CAN	128	140	2.3
NIC	3	56	3.5	BHS	12	145	2.3	RWA	141	426	6.1	ECU	127	244	3.8
GUY	0	21	3.1	CIV	11	26	5.9	MUS	141	218	1.4	BFA	124	473	7.1

River Flood				Coastal Flood				Drought				Multi Hazard			
Country Code	Exposure 2015 Pop (% Change)	Exposure 2050 Pop (% Change)	Vulnerability 2020 (1-10)	Country Code	Exposure 2015 Pop (% Change)	Exposure 2050 Pop (% Change)	Vulnerability 2020 (1-10)	Country Code	Exposure 2015 Pop (% Change)	Exposure 2050 Pop (% Change)	Vulnerability 2020 (1-10)	Country Code	Exposure 2015 Pop (% Change)	Exposure 2050 Pop (% Change)	Vulnerability 2020 (1-10)
BHS	0	0	2.3	MAR	10	71	3.3	BFA	138	509	7.1	SDN	119	323	6.9
CPV	0	0	3.1	MDG	10	10	5.1	MDG	137	433	5.1	CHN	114	102	3
DJI	0	0	6.3	LBR	9	201	6.1	CAN	134	142	2.3	BDI	108	211	6.5
FJI	0	0	2.9	VNM	8	85	2.2	CHN	122	112	3	MDG	106	356	5.1
JAM	0	0	2.5	JPN	7	-43	1.5	MOZ	120	302	7.2	MOZ	100	265	7.2
LBN	0	0	6.2	DZA	6	-11	2.9	BDI	113	219	6.5	SOM	95	304	9.3
MUS	0	0	1.4	GTM	2	59	5.6	TCD	104	292	7.7	NZL	90	110	1
WSM	0	0	3.4	DJI	1	3007	6.3	NZL	101	118	1	COL	82	169	6.1
SLB	0	0	4.1	TKM	1	8477	1.1	COD	93	315	7.8	COD	79	285	7.8
TTO	0	0	2.8	BHR	0	4	1.1	NGA	90	357	6.1	GUY	76	201	3.1
VUT	0	0	3.7	LBN	0	-100	6.2	VUT	90	636	3.7	PNG	74	193	5.5
CMR	-4	55	6.7	ARM	0	0	2.5	COG	86	238	6	NGA	73	323	6.1
ERI	-8	158	4.7	AZE	0	0	4.3	CMR	82	197	6.7	LBR	73	443	6.1
JOR	-10	63	6.1	BRB	0	0	1.5	GHA	82	270	4.2	CMR	71	180	6.7
ZWE	-11	-3	5.9	BLR	0	0	1.3	SLE	81	275	5.3	GHA	71	242	4.2
NAM	-13	22	4.9	BOL	0	0	3.2	BEN	81	244	4.8	FJI	70	175	2.9
CIV	-13	42	5.9	BWA	0	0	3.7	ECU	72	159	3.8	BEN	68	214	4.8
UKR	-15	-28	3.9	BFA	0	0	7.1	FJI	67	303	2.9	SLE	66	229	5.3
RWA	-16	88	6.1	BDI	0	0	6.5	CAF	66	160	9	VUT	59	315	3.7
MWI	-16	124	6.1	CPV	0	0	3.1	COL	66	151	6.1	CIV	54	168	5.9
TCD	-18	64	7.7	CAF	0	0	9	LBR	62	494	6.1	THA	54	76	3
CAF	-18	26	9	TCD	0	0	7.7	CIV	59	178	5.9	TZA	53	249	5.7
GIN	-20	23	4.5	COG	0	-56	6	PNG	58	170	5.5	COG	52	182	6
BFA	-22	106	7.1	COD	0	0	7.8	TZA	56	253	5.7	IND	51	129	4.9

River Flood				Coastal Flood				Drought				Multi Hazard			
Country Code	Exposure 2015 Pop (% Change)	Exposure 2050 Pop (% Change)	Vulnerability 2020 (1-10)	Country Code	Exposure 2015 Pop (% Change)	Exposure 2050 Pop (% Change)	Vulnerability 2020 (1-10)	Country Code	Exposure 2015 Pop (% Change)	Exposure 2050 Pop (% Change)	Vulnerability 2020 (1-10)	Country Code	Exposure 2015 Pop (% Change)	Exposure 2050 Pop (% Change)	Vulnerability 2020 (1-10)
SYR	-22	63	7.7	ETH	0	0	6.5	SSD	50	113	8.5	SSD	50	113	8.5
BLR	-22	-32	1.3	JOR	0	-100	6.1	UGA	39	300	7	VNM	47	100	2.2
CRI	-22	15	3.4	KAZ	0	0	0.7	IND	38	110	4.9	CAF	46	128	9
GHA	-22	42	4.2	KGZ	0	0	2.2	KEN	37	179	6	TCD	42	176	7.7
MAR	-24	-6	3.3	MWI	0	0	6.1	URY	29	49	2.3	UGA	41	306	7
COG	-26	60	6	MLI	0	0	6.4	ETH	26	135	6.5	KEN	38	179	6
NOR	-28	-26	2.1	MUS	0	0	1.4	IDN	16	43	3.3	URY	33	64	2.3
PSE	-29	-36	6.4	MDA	0	0	1.9	JPN	12	-16	1.5	ETH	23	129	6.5
SUR	-34	-11	2.7	NRU	0	0	4.1	SLB	8	215	4.1	IDN	19	45	3.3
MLI	-35	56	6.4	PSE	0	0	6.4	PAN	2	47	2.8	BHS	17	144	2.3
DZA	-38	-21	2.9	PRY	0	0	2.9	ATG	0	0	1.5	SLB	11	149	4.1
SEN	-49	5	5	RWA	0	0	6.1	BHR	0	0	1.1	JPN	11	-27	1.5
MRT	-53	-21	5.6	WSM	0	0	3.4	BRB	0	0	1.5	PAN	4	80	2.8
LBY	-57	-25	5.2	SYC	0	0	1.6	NRU	0	0	4.1	BHR	0	4	1.1
TUN	-71	-66	1.8	SSD	0	0	8.5	WSM	0	0	3.4	BRB	0	0	1.5
ATG	-	-	1.5	SYR	0	0	7.7	SYC	0	0	1.6	NRU	0	0	4.1
BHR	-	-	1.1	TJK	0	0	3.5	SGP	0	0	0.3	WSM	0	0	3.4
BRB	-	-	1.5	TON	0	0	4.6	TON	0	0	4.6	SYC	0	0	1.6
NRU	-	-	4.1	TUV	0	0	3.7	TUV	0	0	3.7	TON	0	0	4.6
SYC	-	-	1.6	UGA	0	0	7	VNM	-12	8	2.2	TUV	0	0	3.7
SGP	-	-	0.3	UZB	0	0	2.1	MYS	-17	25	3.1	MYS	-11	35	3.1
SSD	-	-	8.5	ZWE	0	0	5.9	NOR	-26	-16	2.1	NOR	-21	-28	2.1
TON	-	-	4.6	NOR	-1	-83	2.1	THA	-31	-20	3	PHL	-24	26	4.5
TUV	-	-	3.7	SGP	-100	-100	0.3	PHL	-47	-3	4.5	SGP	-100	-100	0.3

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RECEIPT has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant agreement No. 820712