



SOCLIMPACT



**Downscaling climate impacts and decarbonisation pathways
in EU Islands, and enhancing socioeconomic and non-market
evaluation of Climate Change for Europe, for 2050 and beyond**



SoClimPact project has received funding from the European Union's Horizon
2020 Research and Innovation Programme under Grant Agreement No 77661

Work Package 3:

Climate change vulnerability assessment framework and complex impact chains

**Deliverable 3.2.: Definition of complex impact chains and input-output
matrix for each islands and sectors (Lead: TEC, Participants: GWS, UIB,
BEF, IF, AREAM, ABT, ANCI, OTIE, UA, E3modelling, UCLM, FFCUL)
M 3-12**

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according to the quality review internal process.

Final version -



Coastal and Maritime Tourism



Aquaculture



Marine Energy



Maritime transport

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1. Introduction

1.1. Context

The work within SOCLIMPACT will articulate three approaches: island based (multi-sector), sector-based (to assess all vulnerabilities and impacts within a given sector), and WP-based (to prepare the transfer of data and consistency approach between modelling tasks). We will first identify, through literature review, the main potential impacts of Climate Change on the sectors covered and rank them by the degree of importance. Second, we will identify the main climate parameters related to a given impact in a sector /island (exposure), identify and weight the factors determining the biophysical and economic sensitivity of each island case study to Climate Change (WP3 - WP4 interface), and the social effects that can result of these changes, including components of adaptive capacity (WP4 - WP5 interface). Third, we will assemble these components in conceptual and theoretical impact chains. These impact chains will be confronted to the field, via sector leaders and island focal points.

1.2. Objectives and Outline

SOCLIMPACT improves a climate change risk assessment, helping islands to identify their climate change related risks or to test their existing risk management strategies under climate change and therefore identify sectorial challenges where new strategies are needed.

Following these steps, the SOCLIMPACT project will operationalize with a modelling chain between WP4-WP5 and WP6 the outputs of WP3: some relevant impact chains, selected after each step of WP3 will be modeled.

- o A first step of risk screening allows sector leaders to conduct a desk-top study and screen the climate change-related exposure of each sector using readily available datasets, which are registered in the D3.3 and D3.4.
- o A second step risk assessment takes a standard risk-based approach using national data, local information and expert knowledge in order to formalize some theoretical impact chains.
- o A third step (detailed) risk assessment process allows sector leaders and islands focal points to further investigate short-listed impact chains and provides support to prioritise sectors and/or sub-risks.

The collected information is the result of several meetings between the partners:

- Contributions from the sector leaders of the project: ULPGC for Coastal and Maritime Tourism, CETECIMA for Maritime Transport, ITC for Marine Energy and AquaBioTech Group for Aquaculture
- Contributions from the sector teams during online meetings
- WP3, sector leaders and IFPs online meetings
- WP3 meeting in Corsica (May 2018)
- WP3 and WPs linkages meeting in Roma (October 2018)

2. Concept, Data & Methodology

2.1. AR5 Concept of risk

The IPCC report (https://www.ipcc.ch/pdf/special-reports/srex/SREX_Full_Report.pdf) about "Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX)" assesses how exposure and vulnerability to weather and climate events determine impacts and the likelihood of disasters (disaster risk).

Figure 1 relates to the interaction of climatic, environmental, and human factors that can lead to impacts and disasters, options for managing the risks posed by impacts and disasters, and the important role that non-climatic factors play in determining impacts.

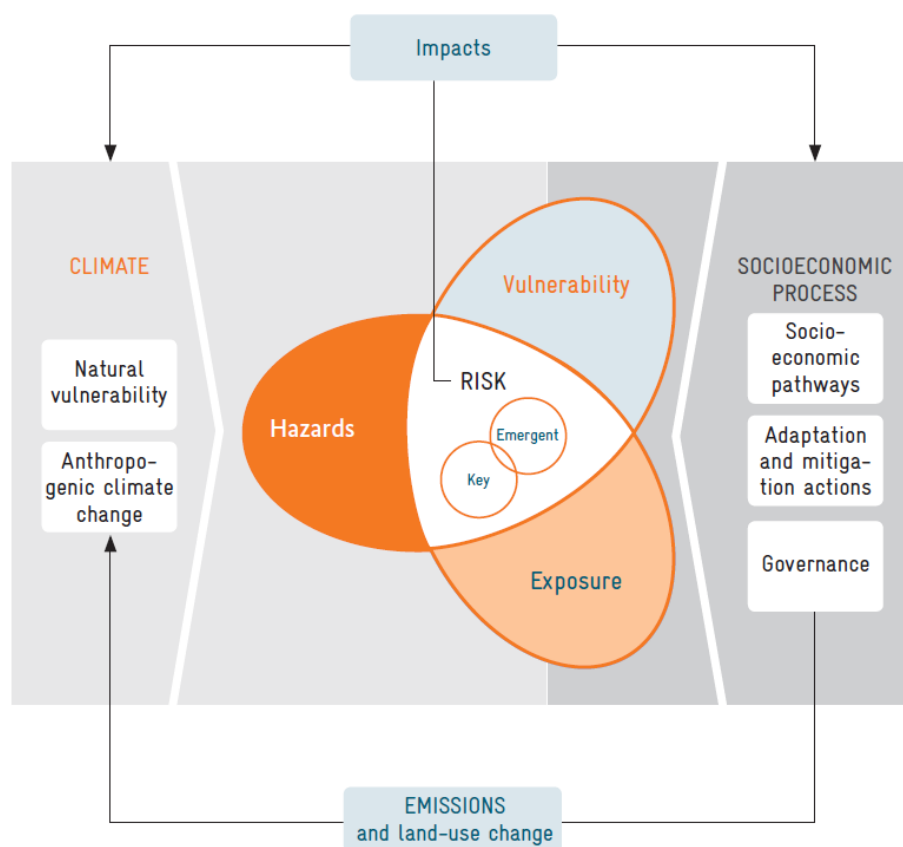


FIGURE 1: SREX CONCEPT OF RISK

According to the last IPCC report (glossary, 2014), the risk is "the potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as probability or likelihood of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. In this report, the term risk is often used to refer to the potential, when the outcome is uncertain, for adverse consequences on lives, livelihoods, health, ecosystems and species, economic, social and cultural assets, services (including environmental services) and infrastructure".

The IPCC AR5 risk concept has been developed around the central term ‘risk’. In this concept, risk is a result of the interaction of vulnerability, exposure, and hazard

2.2. The Impact Chain diagram tool

Impact chains are an excellent way to synthesize in a diagram the complex relationships between exposure (to climate parameters), sensitivity (related to physical and socio-economic features of the island), and adaptive capacity.

To reduce the vulnerability to climate change, the risks and vulnerabilities of the different sectors of the SOCLIMPACT project need to be known as well as their drivers. An important step is therefore to conceptualize and understand the relationships between the first-order risk domains and the second-order risk domains. Thus, we propose to apply the Impact Chain methodology. The Impact Chain method is a highly participative, holistic approach: With the sector leaders, island focal points (IFPs) and other stakeholders (experts in the Local Working Groups), we will develop these Impact Chains’ to understand and to achieve a shared perspective on climate risks and vulnerabilities.

The concept of the Impact Chain (IC) was first published by *Schneiderbauer et al.* (2013), and then “catalyzed” by the German cooperation (GIZ) in the Vulnerability Sourcebook (*Fritzsche et al.*, 2014). Impact chains have since become more and more widely used as a climate risk assessment method, in Europe and abroad (cooperation projects like GIZ, UNDP or World Bank, Horizon 2020 projects like SOCLIMPACT or RESIN), at local or regional or European level, for research and decision making. The methodology can be used for both high-level identification of key risks as well as more in-depth analysis of specific risks and adaptation strategies.

For the SOCLIMPACT project, the impact chain approach is proposed as a high-level method to develop insight in cause-effect relations regarding different risk domains. IC diagrams articulate the causal links between the different components of climate risks. Various concepts and terms of Risk and/or Vulnerability are used in literature. According to the Fifth Assessment Report (IPCC AR5) Risk is the central concept, which is influenced by hazards, exposure and vulnerability, while the Fourth Assessment Report (IPCC AR4) regarded Vulnerability as the central concept, which is determined by the components of exposure, sensitivity, intermediate impacts and adaptive capacity (Figure 2).

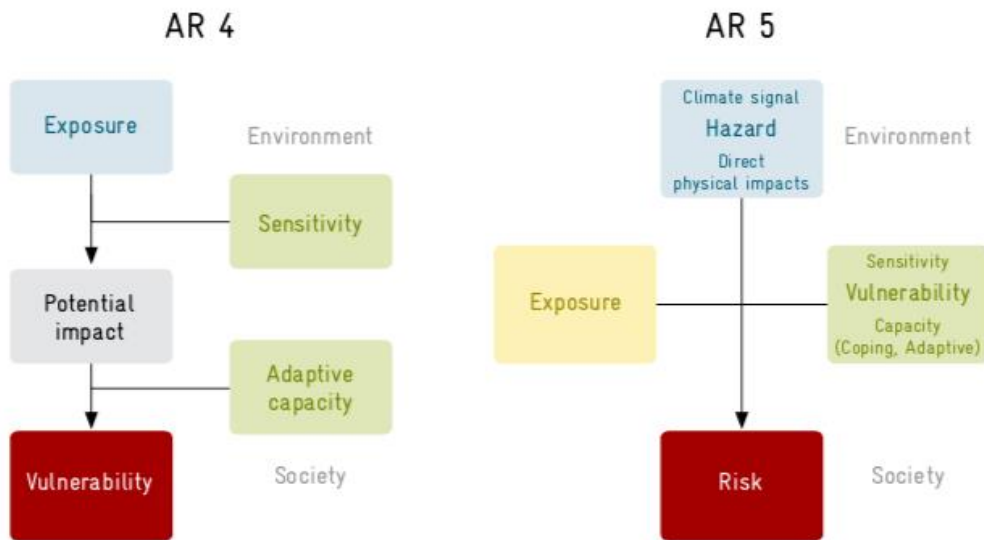


FIGURE 2: CONCEPTS OF RISK ACCORDING TO THE IPCC AR4 REPORT (LEFT) AND IPCC AR5 REPORT (RIGHT). SOURCE: (GIZ & EURAC, RISK SUPPLEMENT TO THE VULNERABILITY SOURCEBOOK. GUIDANCE ON HOW TO APPLY THE VULNERABILITY SOURCEBOOK'S APPROACH WITH THE NEW IPCC AR5 CONCEPT OF CLIMATE RISK, 2017)

We use the most recent IPCC AR5 conceptualization of Risk, using the components of Hazard, Exposure and Vulnerability. In this conceptualization, Climate Hazards lead to a Risk, however, the actual Risk is influenced by the level of Exposure and the level of Vulnerability. Gaining insight into the different components allows us to better identify adaptation options to mitigate climate risk. These adaptation options consider engineering options (e.g. embankments, irrigation systems etc.), nature-based options (e.g. developing flood plains) and soft adaptation options (e.g. awareness rising through education and training, warning systems, land use and spatial planning etc.). Ecosystem-based Adaptation is being increasingly recognized as a cost-effective and low-regret solution for changing climate conditions, incorporating ecosystem biodiversity and ecosystem services and producing social, economic, health and cultural co-benefits. Therefore, in developing the impact chains and carrying out the risk assessments we will carefully consider the connections and interdependencies between humans, sustenance, ecosystems and ecosystem services (GIZ, EURAC, & UNU-EHS, Climate Risk Assessment for Ecosystem-based Adaptation, 2018).

Using Impact Chains as a conceptual framework allows integrating both quantitative and qualitative results from different disciplines, using a participatory approach will facilitate a better understanding and dialogue. They increase the usability of climate projections and climate impact models, illustrating their results and formatting them in a more understandable format. The implementation of an IC can involve a sophisticated modelling chain, or it can support quick diagnosis. ICs have the capacity to be cross-sectoral and cross scales and allow to aggregate or downscale risks and compare sectors.

Box 1: The impact chain diagram tool

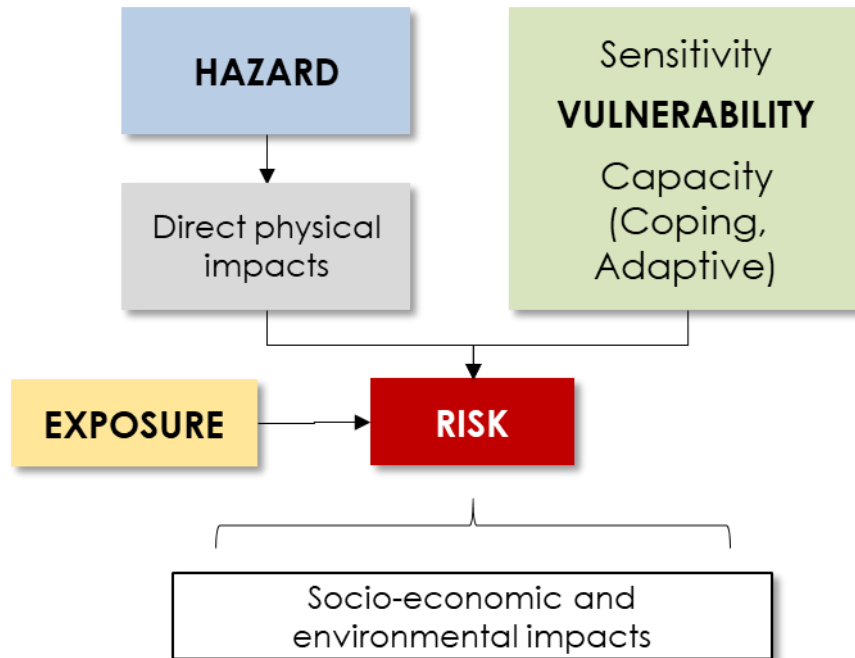


FIGURE 3: THE SOCLIMPACT DIAGRAM

A theoretical impact chain is a diagram tool, which synthesizes the relationships between different climate shocks, ecosystem services and economic activities under study.

The component definitions in the SOCLIMPACT project are the following:

- A climate socio-economical risk is the **potential for climate - related consequences** (climate impacts) for something of **value** (= assets, people, ecosystem, culture, *etc.*).
- The hazard is the **potential occurrence** of a **climate-related physical event** or **trends** or their **physical impact** that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources.
- The exposure is the **presence** of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected.
 - Exposure is related to specific **exposed elements** (or elements at risk), e.g. people, infrastructure, ecosystems.
 - The **degree of exposure** can be expressed by **absolute numbers, densities or proportions** etc. of the elements at risk (e.g. population density in an area affected by drought)

- The vulnerability is the propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including **sensitivity** or **susceptibility to harm** and **lack of capacity to cope and adapt**.
- **Sensitivity** may include **physical attributes of a system** (e.g. building material of houses, type of soil on agriculture fields), **social, economic and cultural attributes** (e.g. age structure, income structure).
- **Capacity** refers to the **ability** of societies and communities to **prepare for and respond to current and future climate impacts**.

The Impacts are the **effects on natural and human systems**: effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure due to the **interaction of climate changes or hazardous climate events** occurring within a specific period and the **vulnerability** of an **exposed society or system**.

The various Risks considered in the Impact Chains (IC) will impact different socio-economic variables. **These impacts can be distinguished depending on whether they directly affect the demand side or the supply side**, by shifting them (or affecting the slope of these curves, if the price elasticity of the demand or of the supply are affected). Apart from this direct effect, the impacts could produce externalities (either positive or negative), which will affect the price and quantity exchanged in equilibrium (for instance, in the negative externality the private cost is lower than social cost; so, the quantity produced in equilibrium is higher than the optimal one). The effects produced by the externalities can be modelled by shifting the demand or the supply (or by shifting their slope if it is considered as a tax). Moreover, spill over effects over into other sectors could also be produced.

2.3. Workflow and steps

The GIZ methodology (GIZ & EURAC, 2017) relies on the following steps:

- 1- Identify climate impacts and risks
- 2- Determine hazard and intermediate impacts
- 3- Determine vulnerability
- 4- Determine exposure
- 5- Brainstorm adaptation measures (optional).

In the SOCLIMPACT project, the following steps have been developed:

- The selection of “priority impacts” (D3.1.) with the sector teams (including sector leader and partners),
- The identification of risks with the sector teams and IFPs during some online meetings and the synthesis during the meeting in Corsica
- The construction of theoretical impact chains, filling the components (hazard, intermediate impact, vulnerability, exposure and impacts with demand-side and supply-side) with the sector teams for the generic IC and with the IFPs for the specific IC – the specific IC are developed by the IFPs when a case study is very relevant for the island.

It will be impossible to compute all IC for all islands due to lack of data, not relevancy, lack of local interest or human resources needed. Considering these points, the SOCLIMPACT project needs criteria: with a sector perspective, with stakeholders needs, keeping project consistency (island comparability) and WPs expectations.

3. Results: from the risk to the ICs

Three steps allowed to design impacts chains: a first reflexion about the priority impacts (D3.1.), then the criteria to define relevant theoretical impact chains.

3.1. Criteria for the design of theoretical impact chains

The objective of SOCLIMPACT is to give a global vision of the blue economy for the European islands but also to feed the local adaptation measures.



An inter-comparison between the islands is important but also to characterize the specificities of each island. Therefore, the criteria that can help to set up the theoretical impact chains of the four sectors, considering socio-economic and spatial priorities, considering that the SOCLIMPACT project deals essentially with two different climatic zones with the European islands of Atlantic Ocean and of the Mediterranean Sea.



Depending on several typologies considering the sector, the socio-economic and zonal criteria and/or scales studies and according to relevant criteria, the choice of socio-economic risks has been realized.

By sector (elaborated by sector leaders) with socio-economic variables

The main variables considered are summarized in the table 1. Depending on the sector's challenges, an adapted methodology for each one allows to characterize the relevant theoretical impact chains.

TABLE 1: EXAMPLES OF RELEVANT SOCIO-ECONOMIC CRITERIA FOR BLUE ECONOMY SECTORS

	<ul style="list-style-type: none"> • Different seasonal variation in tourism activities • Annexe 1.
	<ul style="list-style-type: none"> • Different dependence on aquaculture activities • Number aquaculture companies • Number of people working in the aquaculture sector • Types of aquaculture <ul style="list-style-type: none"> ○ Offshore, cage, coastal, etc. ○ Species • Size of sector in production (kilo) and monetary value (€) • Vulnerability level of aquaculture • Previous damage or loss from weather events <ul style="list-style-type: none"> ○ Storms, temperature change, etc. • Potential growth of the sector in the future

	<ul style="list-style-type: none"> • Installed power (MW) • Power generation (GWh) • Energy intensity (kWh/€ of GDP) • Share of renewable energy sources in island energy mix (% of RES penetration) • Decrease in quality and reliability of power supply <ul style="list-style-type: none"> ○ Outage time. Equivalent Interruption Time of Installed Power in medium voltage. 1 kV <V <= 36 kV ○ Number of outages. Number of Equivalent Interruptions of Installed Power in medium voltage. 1 kV <V <= 36 kV • Cost of power supply <ul style="list-style-type: none"> ○ Increase in cost of installation and maintenance of energy infrastructure ○ Increase in energy prices • Increase in energy demand due to increase in temperature <ul style="list-style-type: none"> ○ Per capita energy demand ○ Energy demand in primary, secondary and tertiary sectors • CO2 emissions <ul style="list-style-type: none"> ○ Energy CO2 emissions per capita • Energy CO2 emissions per unit of GDP
	<ul style="list-style-type: none"> • Gross weight of goods transported • Number of passengers/years • Number of passengers/year (only cruises) • Population of the island where the port is located

By zonal criteria

Different geographical and climatic area and different countries are considered in the project and some impacts chains will be relevant for the Mediterranean islands: for example, certain issues as forest fires are generally more relevant in the Mediterranean islands than in the Atlantic islands or some species of fish for aquaculture present in the Atlantic area only.

By IFPs

The availability of specific data is also relevant for “island-scale” modelling depending on the access to specific data for vulnerability and exposure criteria, for example. Indeed, for the modelling of the hazard component or more generally concerning the outputs of climate models (within the WP4), it is possible to obtain certain variables with a Mediterranean basin resolution (D4.1.) for example.

Nevertheless, to give a fair assessment for each island and to consider specificities, IFPs will be able to judge both the importance of a chain of impacts for the island in question and the availability of data during the first LWGs.

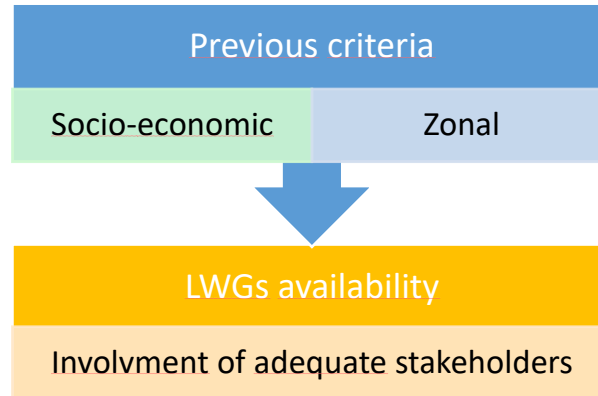


FIGURE 4: TREE OF DECISION

By scales studies

A scientific reflexion is needed at the spatial level within the project (Figure 5). To compare islands, it is necessary to obtain interoperable datasets but also consider the diversity of the climate zones within the project and the specificities related to each island: only some develop aquaculture and can be studied in detail, for energy it is the same dynamic (see the matrix of interests).







FIGURE 5: REFLEXION ABOUT SCALES

3.2. Socio-economic risk selection

Each leading sector has organized the selection of the priority risks to be dealt with within the project with its team. The procedure is explained in Table 2.


TABLE 2: PROCEDURE FOR EACH SECTOR




	<p>To determine the main socio-economic risks, three categories are considering:</p> <ul style="list-style-type: none"> • Ecosystem <ul style="list-style-type: none"> • Distinction between biotic degradation (species) and abiotic environment (beach and forest) • Human being (health or comfort) • Infrastructure & facilities <p>Measure impact of risk as change (decrease) in willingness to pay due to a given change. [Tourist experience value]. This can be translated into decrease in tourist arrival; decrease in income (agencies) or tourist expenses in destination; <i>etc.</i></p>
	<p>To identify the socio-economic risks, the table made in 3.1 (done using literature) is used. The impact chains were adjusted considering the GIZ methods and sourcebook, then in Corsica during the workshop.</p> <p>In the sector group, it was only discussed with AREAM and some adjustments were made too.</p> <p>A questionnaire was sent to see on which islands aquaculture is relevant (Annexe 2)</p> <p>The main relevant literature is:</p> <p>Barange <i>et al.</i> 2018. FAO Technical paper 627 Impacts of climate change on fisheries and aquaculture</p> <p>Cochrane <i>et al.</i> 2009. FAO Technical paper 530 Climate change implications for fisheries and aquaculture</p>
	<p>Work on selection of the socio-economic risks of Marine Energy started at a brain storm session, with the participation of the core energy group members: GWS, ULCM, TEC and ITC. The session took place at the at the Corsica meeting, held on May 15, 2018.</p> <p>The approach of the IC energy sector group for identifying elements of climate change affecting the marine energy and island energy system in general, began by desegregate the value chain of energy in three:</p> <ul style="list-style-type: none"> <input type="checkbox"/> Generation (both marine RES but also conventional fossil back-up power installed on islands) <input type="checkbox"/> Transmission (submarine cables, but also transmission lines, substations, and other energy infrastructure needed to feed marine energy to energy consumers in the islands) <input type="checkbox"/> Consumption (looking at changes on energy consumption resulting from climate change, and the possibility of having non-critical loads contributing, from the demand side to the balancing of the island electrical grids, compensating the fluctuation and variability of marine RES generation. <p>The energy sector group first focussed in identifying Hazard components of climate change that where relevant and for the risk analysis in the three IC. Among the factors identified that affect the three risk IC are: Frequency & intensity of Extreme events; Wind; Solar radiation; Waves; Temperature; Humidity; Ocean temperature; Dust; Drought; Flood.</p> <p>Afterwards the group proceeded to identify Intermediate risks and specific Exposure and Vulnerability factors in each of the three socio-economic Risk IC. After the Energy sector group members agreeing on exposure and vulnerabilities,</p>

	<p>the discussions moved towards identifying the Risk. For the three IC the main risks are: Change in power generation; Damages to energy infrastructures; increase in energy demand.</p> <p>Finally, the Energy sector group addressed the Impacts (socio economic and environmental) for the three IC. From the discussions, a long list of potential factors were identified, but after a more thorough analysis, a shorter list of impacts were obtained. Mayor risk are related to increase in cost, both investment and M&O; risk of loss of quality and guarantee of power supply, including risk of black-out and frequent power outages.</p> <p>After producing the three general IC diagrams, island focal points were requested to adapt them to the specificities of each of the 12 participating island regions. There is a diversity of situations all over the different islands; some of them are interconnected to continental electrical systems, and others are totally isolated island systems; some have high potential of wind, others have higher potential for solar; some dispose of massive energy storage systems or are in the process of installing such systems; some islands high seasonal energy demand, others have a more or less constant yearly demand, but are suffering of high daily variations in the electric demand curve.</p>
	<p>The maritime transport impact chains (IC) were prepared following the instructions provided by the WP3 Leader (TEC). After an initial meeting with maritime transport experts, the main elements were classified as hazards, biophysical impacts (both positive and negative), and socio-economic impacts. The identification of these elements was supported by bibliography consulted by the sector leader.</p> <p>Thus, the elements (hazards and impacts) were organized in draft versions of the ICs. In order to prepare them, the IC methodology proposed by the WP3 Leader was used. Once the drafts were ready, they were discussed in online meetings attended by the sector team.</p> <p>During the WP3 meeting in Corsica, the sector team, supported by POT members, discussed about the main risks identified and finalised three ICs.</p> <p>The final step was to send the three final ICs to the Island Focal Points to get their feedback and to propose new versions of the ICs adapted to their regional characteristics.</p>

The final impacts chains based on socio-economic risks are summarized in the table 3.

TABLE 3: SUMMARY OF ICS FOR THE 4 BLUE ECONOMY SECTORS

	<p style="text-align: center;">Coastal and maritime tourism</p> <p>1- Loss of tourist experience value in the destination due to changes in environmental attributes</p> <p>1-1- Loss of attractiveness of touristic marine environments (due to loss of species and/or increase of exotic invasive species; or degradation of landscape)</p> <p>1-2- Loss of attractiveness due to increased danger of forest fire in touristic areas</p> <p>1-3- Loss of attractiveness of touristic land environments (due to loss of species and/or increase of exotic invasive species; or degradation of landscape)</p> <p>1-4- Loss of attractiveness and comfort due to beach surface reduction</p>
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	<p>2- Loss of tourist experience value in the destination due to changes in human being comfort 2-1- Loss of comfort due to increase of thermal stress 2-2- Increase of health issues due to emergent diseases</p> <p>3- Loss of tourist experience value in the destination due to the quality of infrastructure and facilities 3-1- Decrease of available domestic water for the tourism industry 3-2- Increase of damages to infrastructures and facilities (accommodation, promenades, water treatment system, etc.) due to sea level rise and storms 3-3- Loss of attractiveness due to loss of cultural and patrimonial heritage (monuments, gastronomy, etc.)</p>
	<p style="text-align: center;">Aquaculture</p> <ol style="list-style-type: none"> 1- Decrease in production due to an increase in surface water temperature 2- Increased fragility of the aquaculture activity due to an increase of extreme weather.
	<p style="text-align: center;">Marine Energy</p> <ol style="list-style-type: none"> 1- Risk of changes in power generation due to long term climate change and variability 2- Risk of changes in energy demand due to changes in precipitations and temperatures 3- Risk of damages to transmission grids due to extreme events
	<p style="text-align: center;">Maritime transport</p> <ol style="list-style-type: none"> 1- Risk of damages in port infrastructures due to floods and waves 2- Damages to ships on route (open water and near coast) due to extreme weather events 3- Risk of transport disruption due to transport disruption

3.3. Matrix of interest

Each IFP expressed in the matrix below its interest for certain ICs considering the main issues of the islands.

The LWGs also made it possible to specify this matrix.

In bold, the priority impact chains and the blue boxes are indicated as possible study cases identified by the IFPs (in Appendix 2, two are detailed).

	# of IC	Risk	Azores	Balearic	Baltic	Canary	Corsica	Crete	Cyprus	Madeira	Malta	Sardinia	Sicily	West Indies
Tourism	1,1	Loss of attractiveness of touristic marine environments	X	X	X	X	X	X	X		X		X	X
	1,2	Loss of attractiveness due to increased danger of forest fire in touristic areas	X	X	X	X	X	X		X		X	X	
	1,3	Loss of attractiveness of touristic land environments	X	X	X	X	X	X	X		X	X	X	X
	1,4	Loss of attractiveness and comfort due to beach availability reduction	X	X	X	X	X	X	X	X	X	X	X	X
	2,1	Loss of comfort due to increase of thermal stress	X	X	X	X	X	X			X	X	X	X
	2,2	Increase of health issues due to emergent diseases	X	X	X	X	X	X			X	X	X	X
	3,1	Decrease of available domestic water for the tourism industry	X	X	X	X	X	X				X	X	X
	3,2	Increase of damages to infrastructures and facilities	X	X	X	X	X	X			X	X	X	X
	3,3	Loss of attractiveness due to loss of cultural heritage	X	X	X	X	X	X	X			X	X	X
Marine energy	1,1	Risk of changes in power generation due to long term climate change and variability			X	X	X	X			X		X	
	1,2	Risk of changes in energy demand due to changes in precipitations and temperatures		X	X	X	X	X			X		X	
	1,3	Risk of damages to transmission grids due to extreme events			X	X	X				X			
Maritime transport	1,1	Damages to ports' infrastructures and equipments due to floods and waves		X		X		X	X		X		X	X
	1,2	Damages to ships on route (open water and near coast) due to extreme weather events				X		X			X			X
	1,3	Risk of isolation due to transport disruption		X		X		X			X			X
Aquaculture	1,1	Decrease in production due to an increase in surface water temperature				X				X	X	X	X	X
	1,2	Increased fragility of the aquaculture activity due to an increase of extreme weather				X				X	X	X	X	X
	1,3	Increased environmental pollution from aquaculture sites due to a too low current speed				X				X	X	X	X	X

4. Impacts chains by sectors

4.1. Coastal and maritime tourism

The largest sector of SOCLIMPACT is the maritime and coastal tourism with 9 impacts chains in three sub-categories. **Generic impacts chains** and **specific impacts chains** summarized all the main socio-economic risks. Specific impact chains need local data from islands depending on sector, *etc.* For the maritime and coastal tourism sector, some case studies have been developed by the IFPs and in the next steps of the SOCLIMPACT project, it will be decided whether these theoretical impact chains can be modelled (Annexe 3 with two studies cases of Madeira and Azores islands)

The Impact Chains (IC) on the maritime and coastal tourism sector have been constructed considering the concept of tourist experience value. This concept has been analyzed in detail in Prebensen, Chen and Uysal (2014)¹. As the authors remark, the tourist experience is an individual perception generated in the context of interactions and resource integrations, and which as a value-in-use for the consumer. Therefore, climate changes affecting the potential destination of the tourist (it could affect its ecosystems, its services, its infrastructures, etc.), will change the perception the tourist has regarding the place, which depends on several attributes or variables. This framework allows us to ultimately analyze the impacts of climate change on the economy by looking at the interaction of the demand and the supply curves. We should observe a change (decrease) in tourists' arrivals and receipts.

In the simplest scenario, this change in tourists' perception will translate into changes in the demand-side (demand of destination, demand of services, etc.). Nevertheless, even if it may seem contradictory and as it will be explained later, in some frameworks we have considered that climate changes could also affect the supply-side. The reasoning relating these changes in the supply-side with changes in the tourist experience value is the following: policy actions should be taken in order to keep the demand curve unaffected (keep the tourist experience value at initial levels), and therefore, these actions will only affect the supply curve (higher cost) and not the demand curve.

The ICs considered for this sector can be summarized in three main categories:

1. Loss of tourist experience value in the destination due to changes in environmental attributes².
2. Loss of tourist experience value in the destination due to changes in human being comfort (or health).
3. Loss of tourist experience value in the destination due to the quality of infrastructure and facilities.

These categories try to summarize all the interactions the tourist can experiment in the destination. Firstly, the environmental attributes could serve as service them-selves (ecosystem service) in the case of tourism devoted to nature observation. However, in most of the cases, the interaction with nature (marine environment, land environment, forests or beaches) will come in the form of activities: sports, hiking, pleasure, *etc.* Secondly, the comfort or health of tourists is important in

¹ Prebensen, N., Chen, J.S., & Uysal, M.S. (2014). *Creating experience value in tourism*. Oxfordshire: CABI.

² A distinction between the biotic degradation (species and forest) and abiotic environment (beach) has been made.

determining the destination. Higher temperatures, frequent precipitations or even the emergence of new diseases due to climate changes or new species, will lower the comfort, and therefore, the tourist experience value. Finally, the quality of infrastructures and facilities available will also affect the perception of the incoming tourists.

The three main IC categories have been divided into 9 ICs (Figure 6 to 17). These subcategories could be considered as general (if they affect the different islands in similar ways, or if there are no characteristics or attributes of the chain) or specific (if ecosystems and species, landscapes or activities are affected in the islands).

TABLE 4: GENERAL AND SPECIFIC ICs OF THE TOURISM SECTOR

General ICs	Specific ICs
1.4. Loss of comfort due to beach surface reduction.	1.1. Loss of attractiveness of touristic marine environments.
2.1. Loss of comfort due to increase of thermal stress.	1.2. Loss of attractiveness due to increased danger of forest fire in touristic areas.
3.1. Decrease of available domestic water for the tourism industry due to changes in climate trends.	1.3. Loss of attractiveness of touristic land environments.
3.2. Increase of damages to infrastructures and facilities due to sea-level rise and storms.	2.2. Increase of health issues due to emergent diseases.
	3.3. Loss of attractiveness due to loss of cultural and patrimonial heritage.

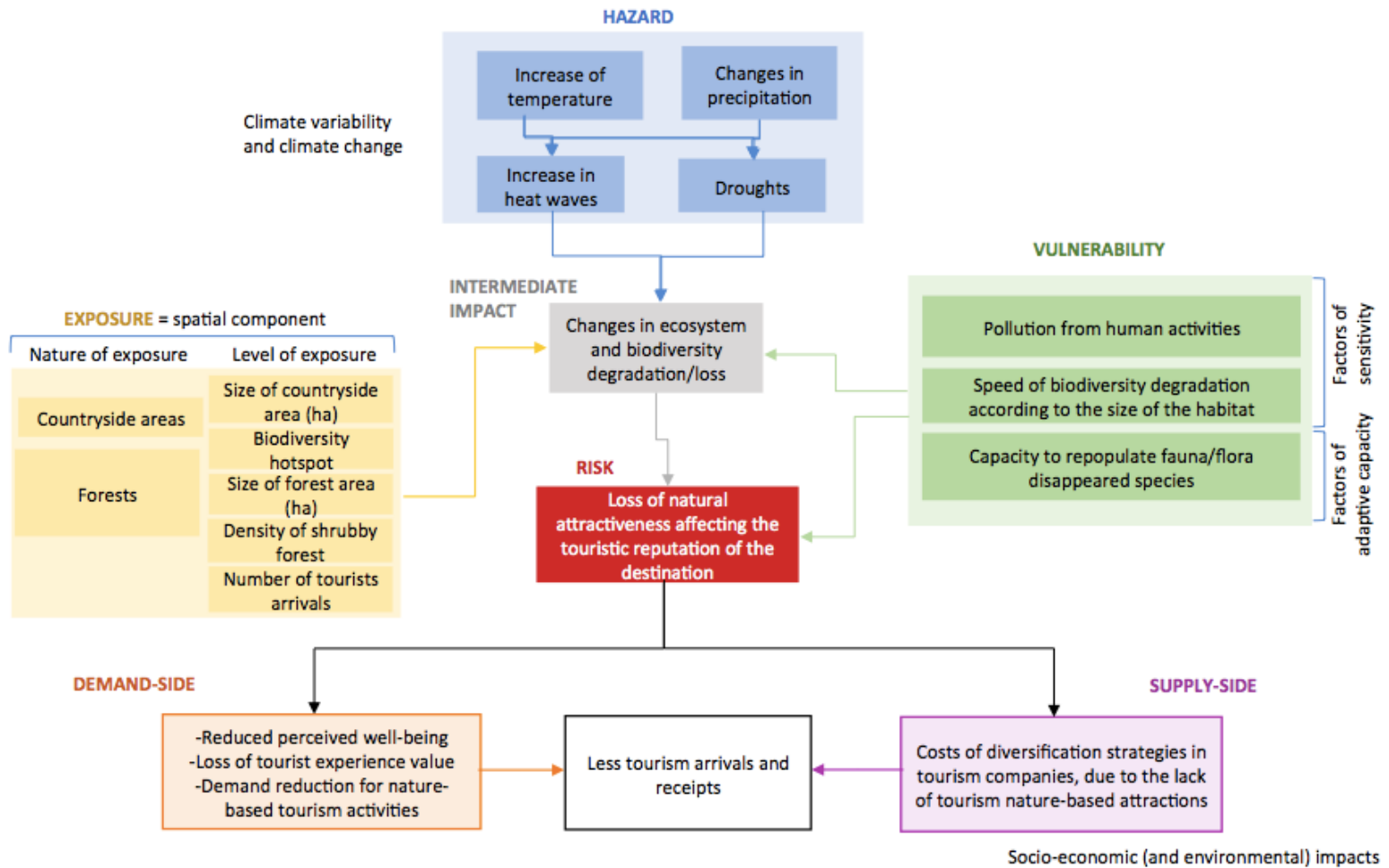


FIGURE 6: 1- LOSS OF TOURIST EXPERIENCE VALUE IN THE DESTINATION DUE CHANGES IN TO ENVIRONMENTAL ATTRIBUTES

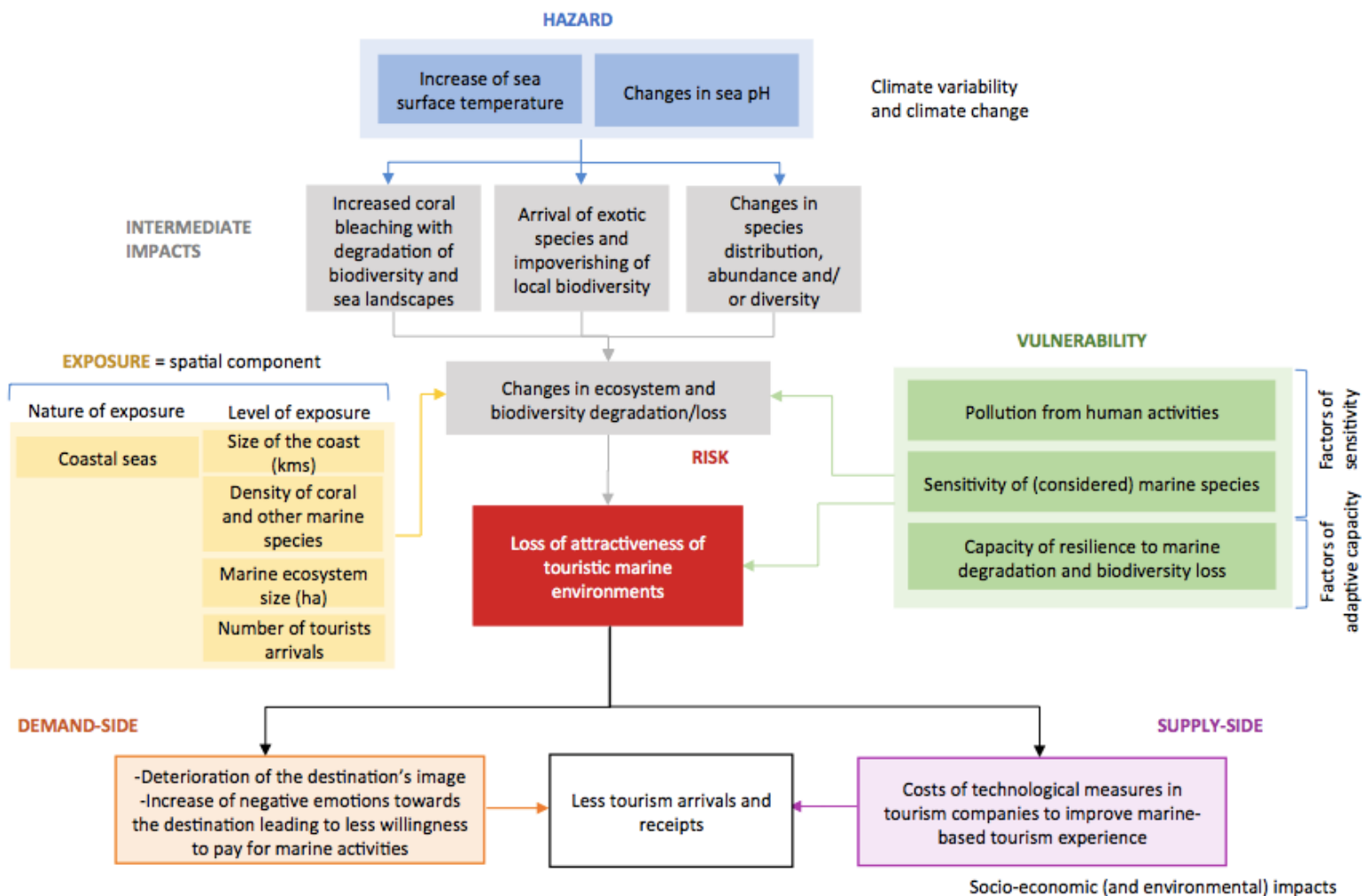


FIGURE 7: 1-1-LOSS OF ATTRACTIVENESS OF TOURISTIC MARINE ENVIRONMENTS

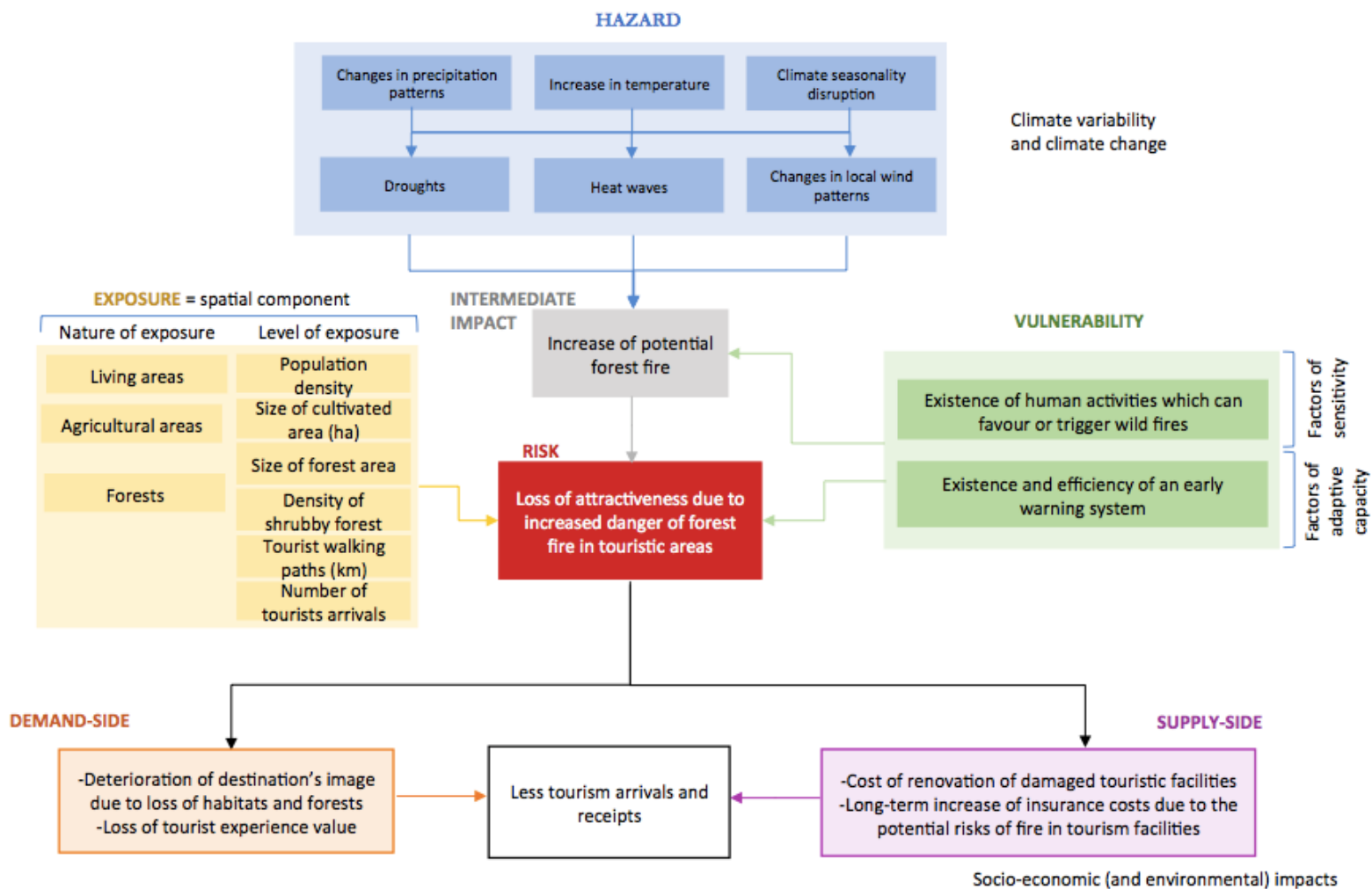


FIGURE 8: 1-2- LOSS OF ATTRACTIVENESS DUE TO INCREASED DANGER OF FOREST FIRE IN TOURISTIC AREAS

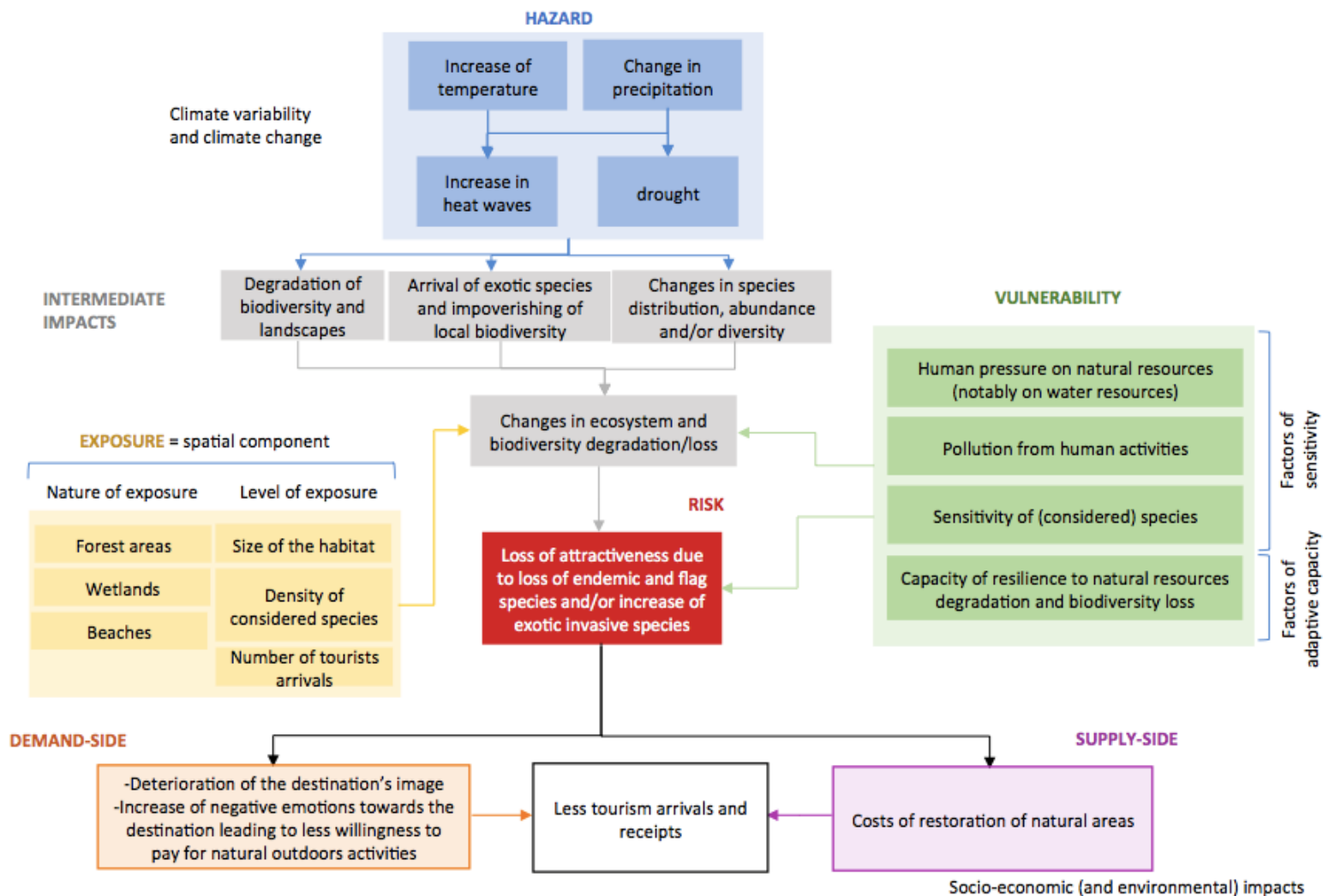


FIGURE 9: 1-3- LOSS OF ATTRACTIVENESS OF TOURISTIC LAND ENVIRONMENTS

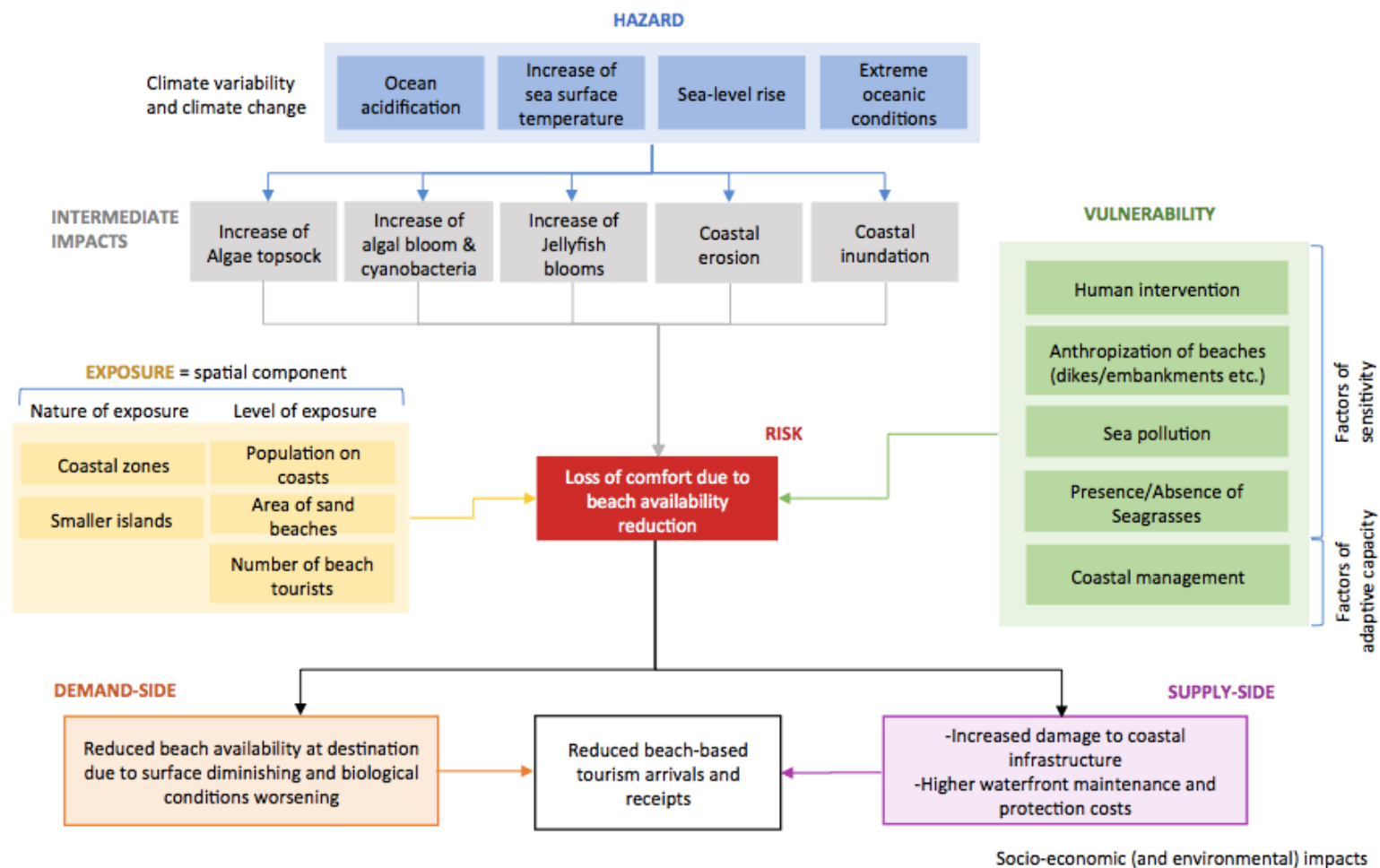


FIGURE 10: 1-4- LOSS OF COMFORT DUE TO BEACH SURFACE REDUCTION

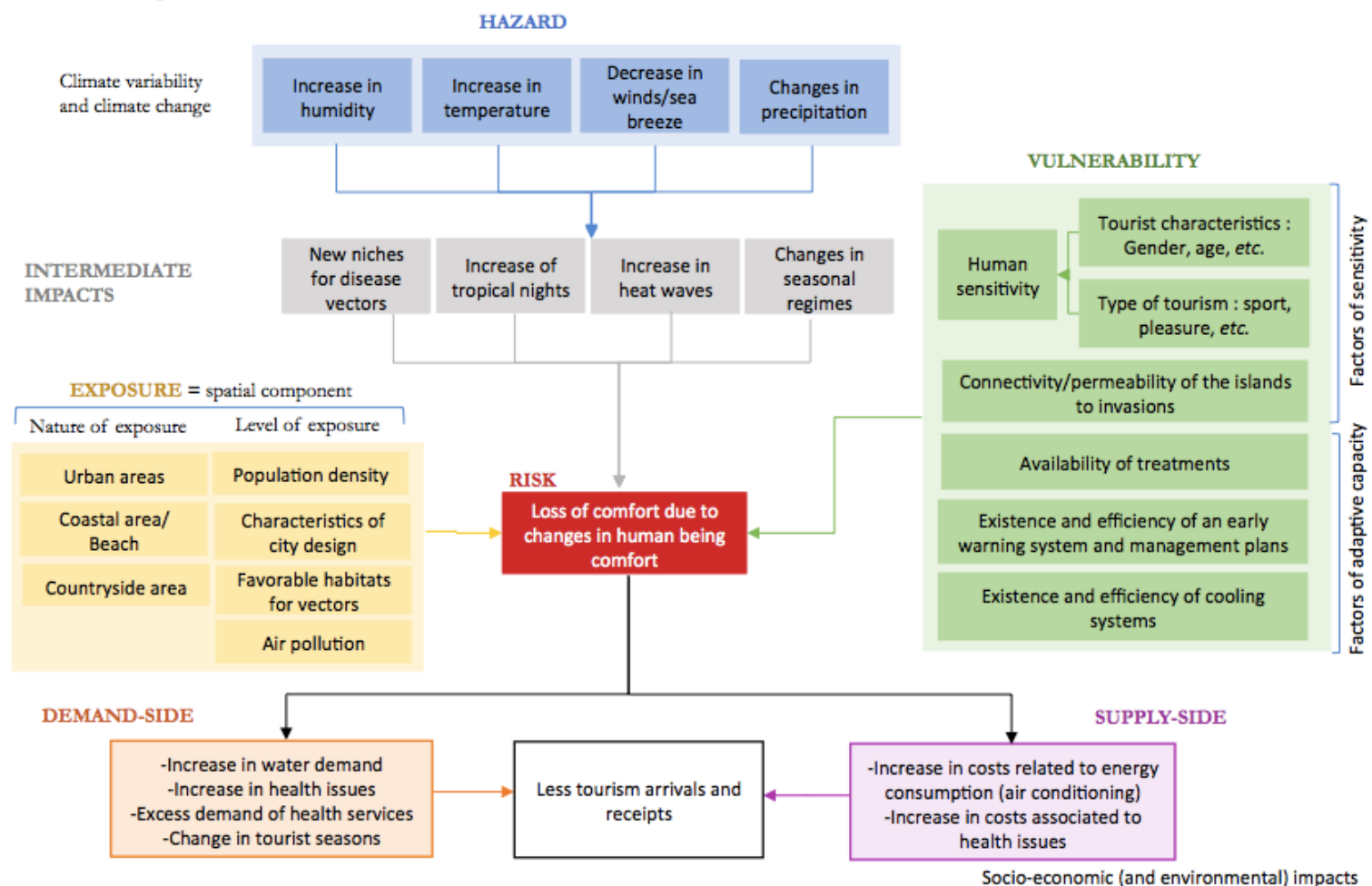


FIGURE 11: 2- LOSS OF TOURIST EXPERIENCE VALUE IN THE DESTINATION DUE TO CHANGES IN HUMAN BEING COMFORT

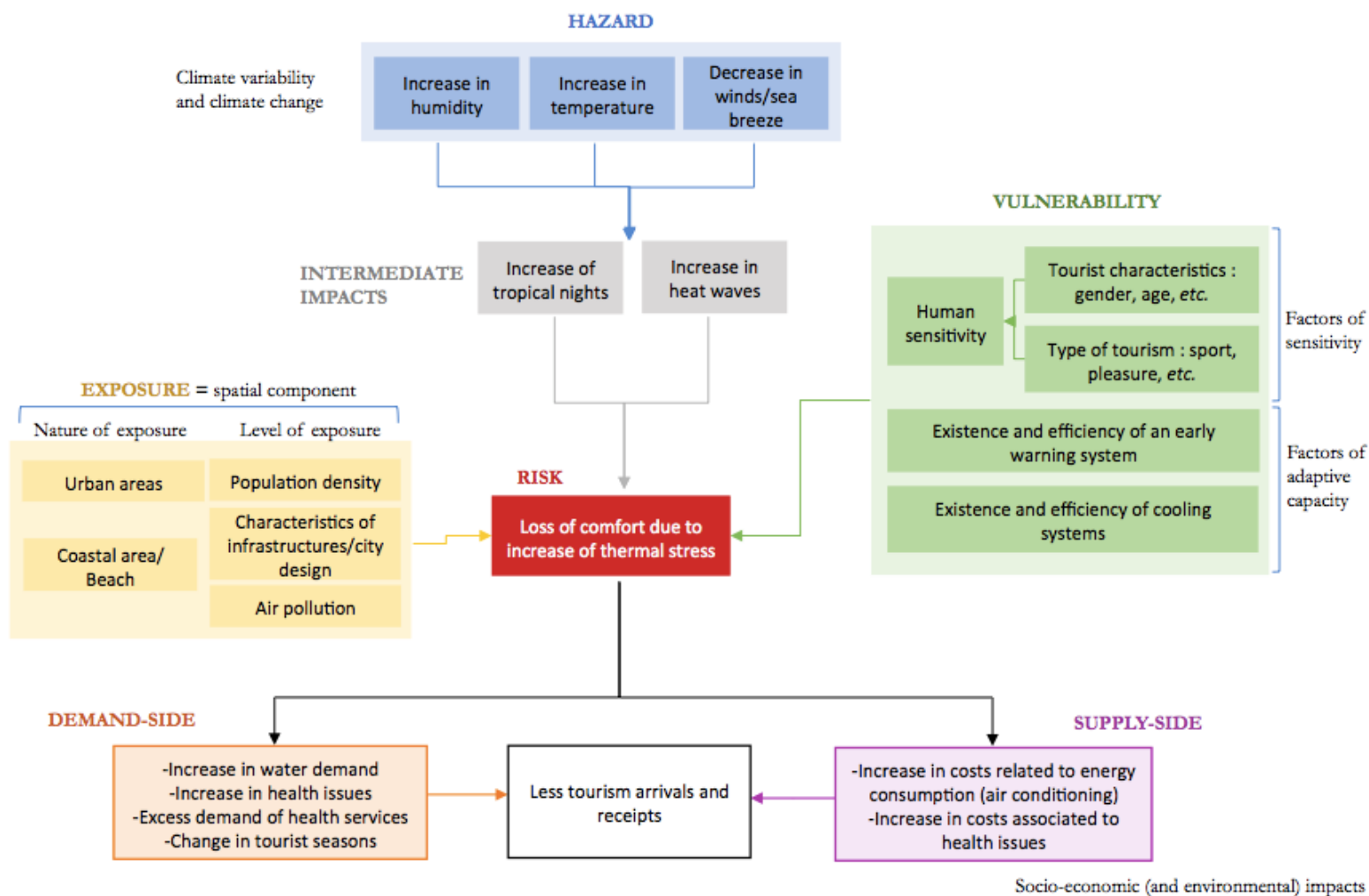


FIGURE 12: 2-1- LOSS OF COMFORT DUE TO INCREASE OF THERMAL STRESS

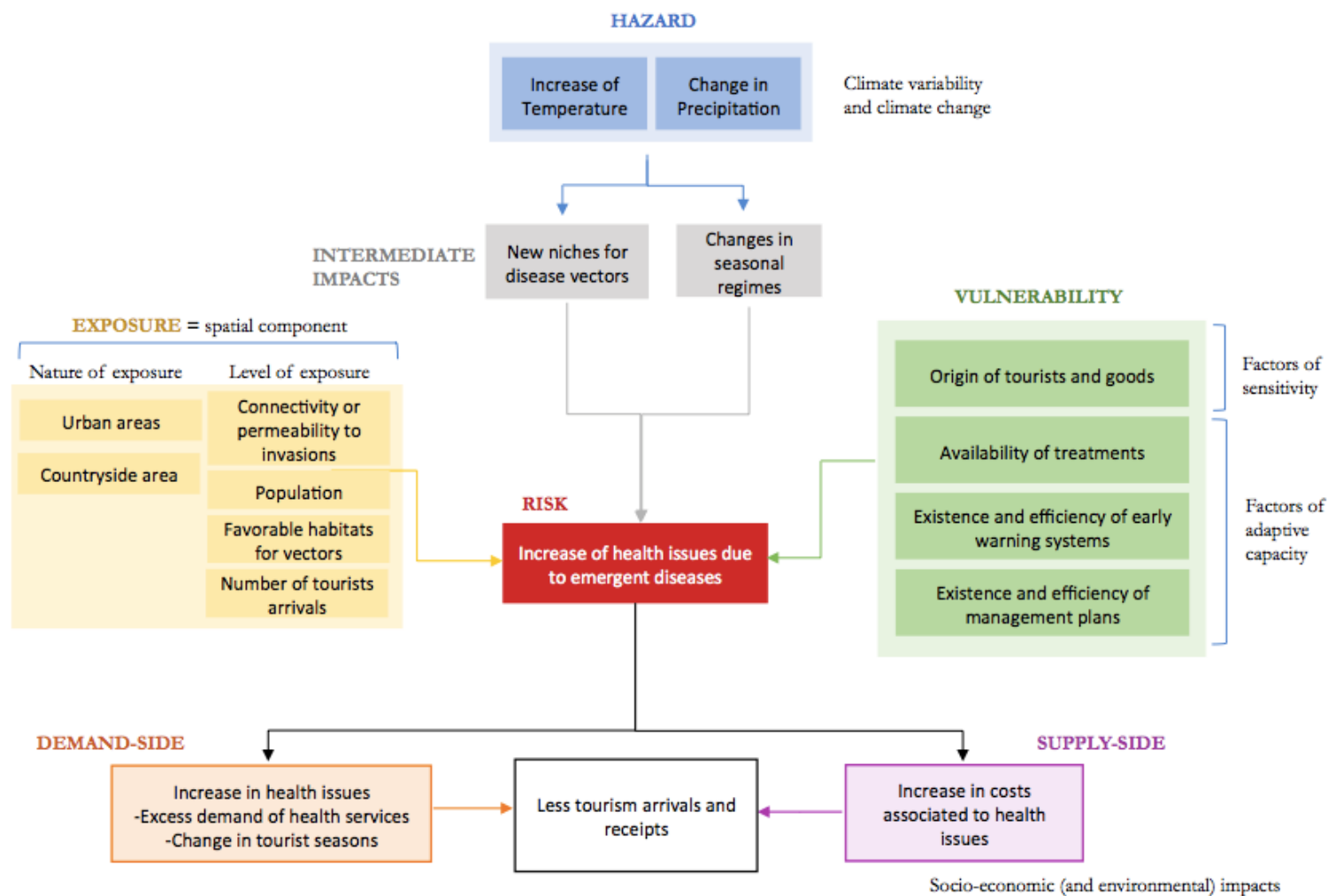


FIGURE 13: 2-2- INCREASE OF HEALTH ISSUES DUE TO EMERGENT DISEASES

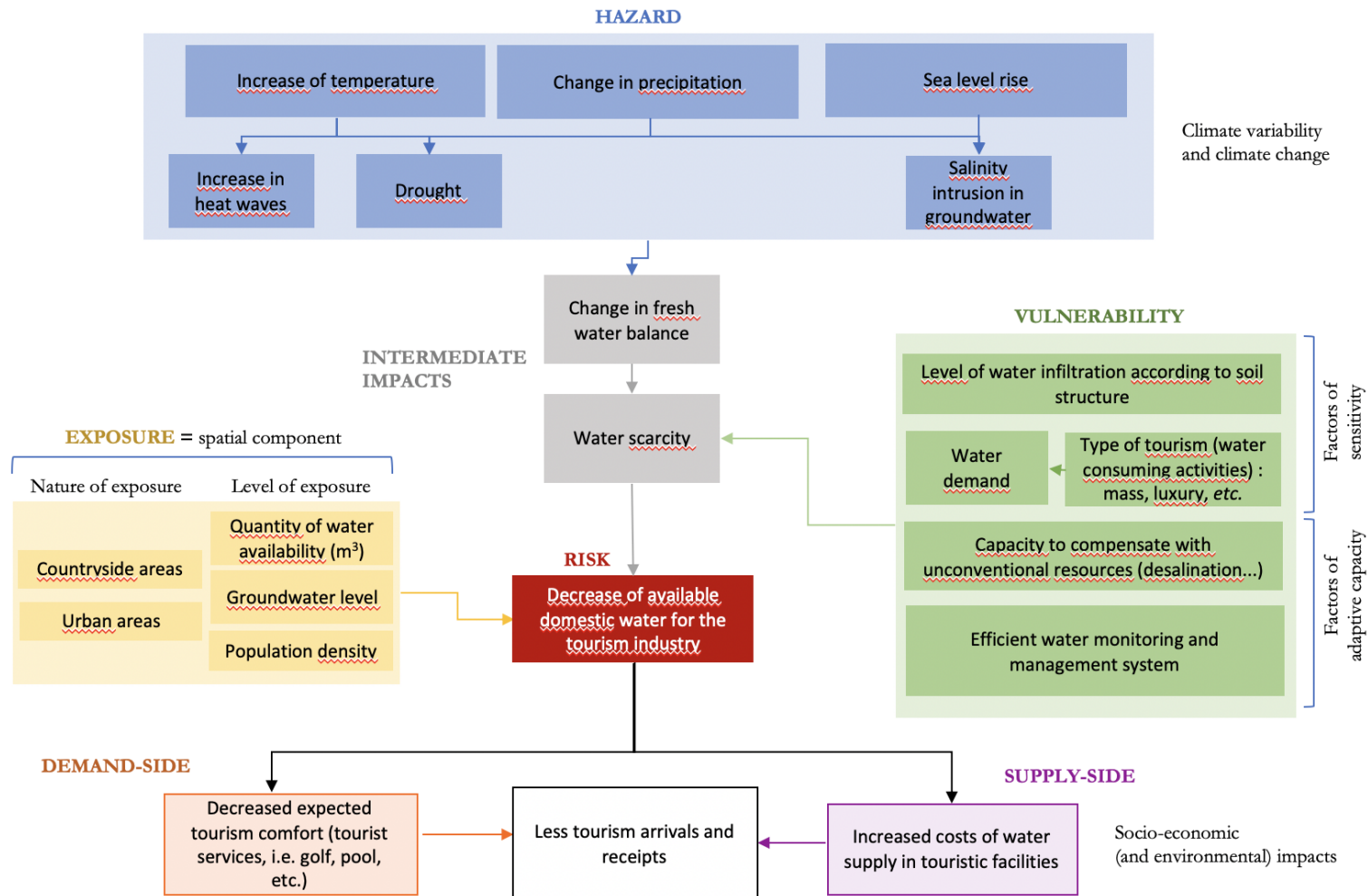


FIGURE 14: 3.1. DECREASE OF AVAILABLE DOMESTIC WATER FOR THE TOURISM INDUSTRY

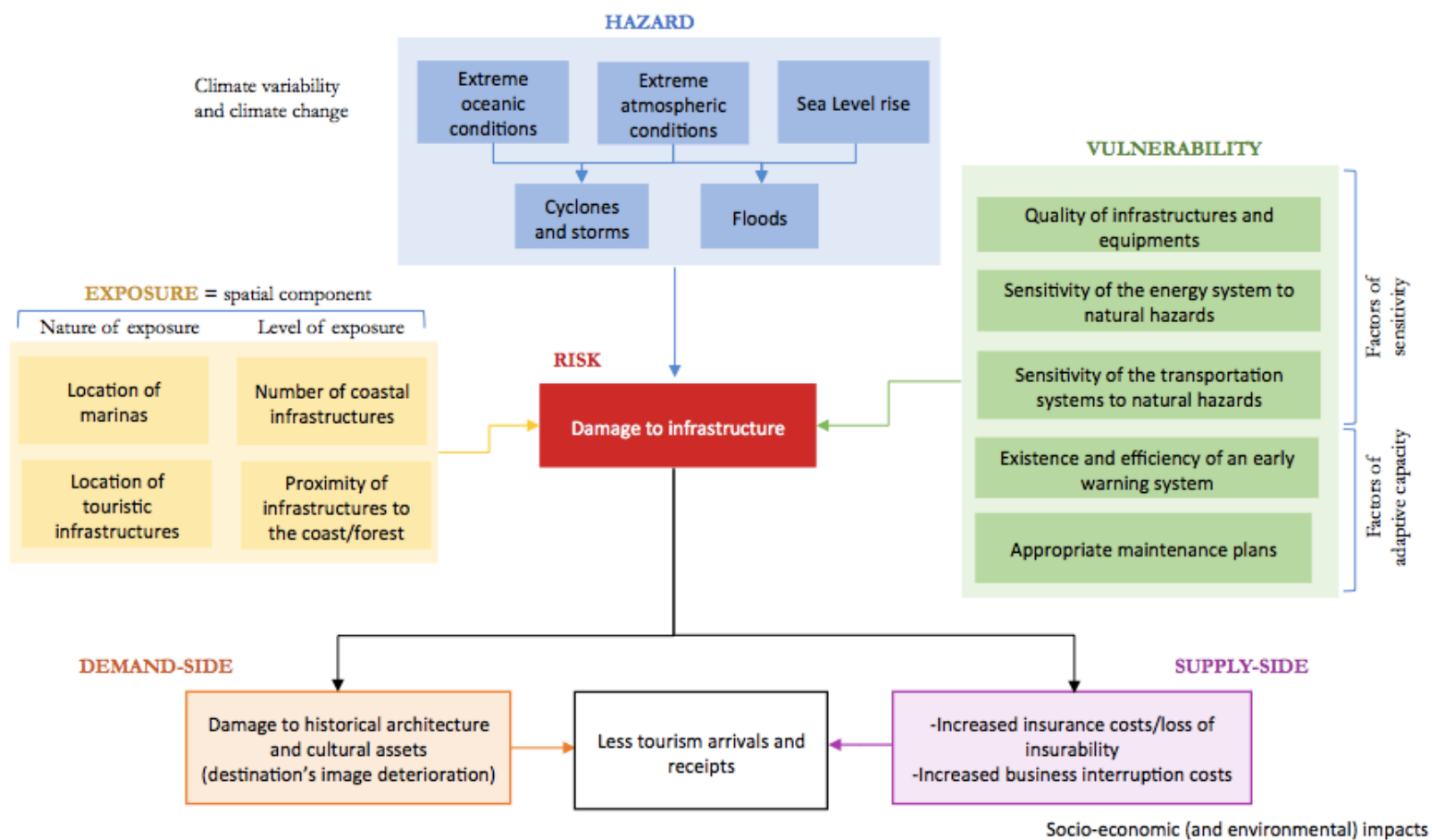


FIGURE 15: 3.2. INCREASE OF DAMAGES TO INFRASTRUCTURES AND FACILITIES (ACCOMMODATION, PROMENADES, WATER TREATMENT SYSTEM, ETC.) DUE TO SEA LEVEL RISE AND STORMS

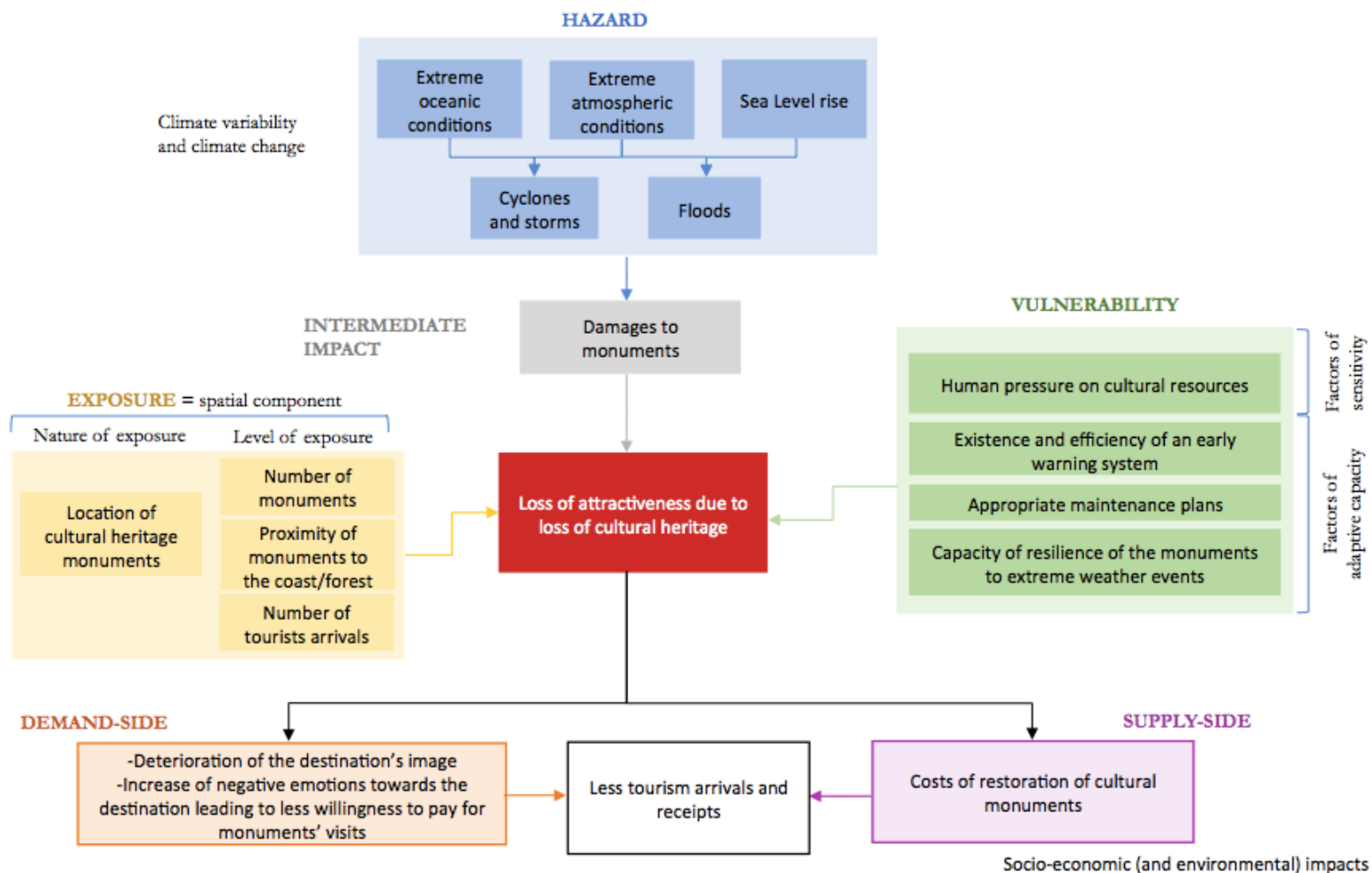


FIGURE 16: 3-3-LOSS OF ATTRACTIVENESS DUE TO LOSS OF CULTURAL HERITAGE

4.2. Aquaculture

Three theoretical impacts chains have been developed at the beginning but finally the third about the following risk was rejected: “Increased environmental pollution from aquaculture sites due to a decrease in current flow” after discussions with experts (LWGs, partners of SOCLIMPACT, etc.) and the leader of the deliverable D3.3. (CMCC) considering that indicators were not relevant in this case.

The following impacts chains have been developed for the aquaculture sector (Figures 18 & 19):

Decrease in production due to an increase in surface water temperature.

SST is the main hazard that impacts the production of fish and shellfish in the sea. It has direct intermediate impacts like increase of growing season, increase risk of diseases, parasites, fouling and algae blooms, increase in FCR, all these lead to a decrease in growth and thus a decrease in income for the farms. This is relevant since to be financially viable, aquaculture operators need to have optimal production. This hazard can also have a positive impact, however in this project only negative effects are taken into account, so this was not included.

Increased fragility of the aquaculture activity due to an increase of extreme weather (high waves and storm surge)

High waves and storms lead to stock loss (mortality) and damage to infrastructure. This leads to increase in costs for the farmers and loss of income. If the species cultured are not local, and the stock is released in the sea this can have a negative impact on the local ecology/food chains. For farmers, the infrastructure and stock are their main assets, therefore looking at the CC impacts on this is very important.



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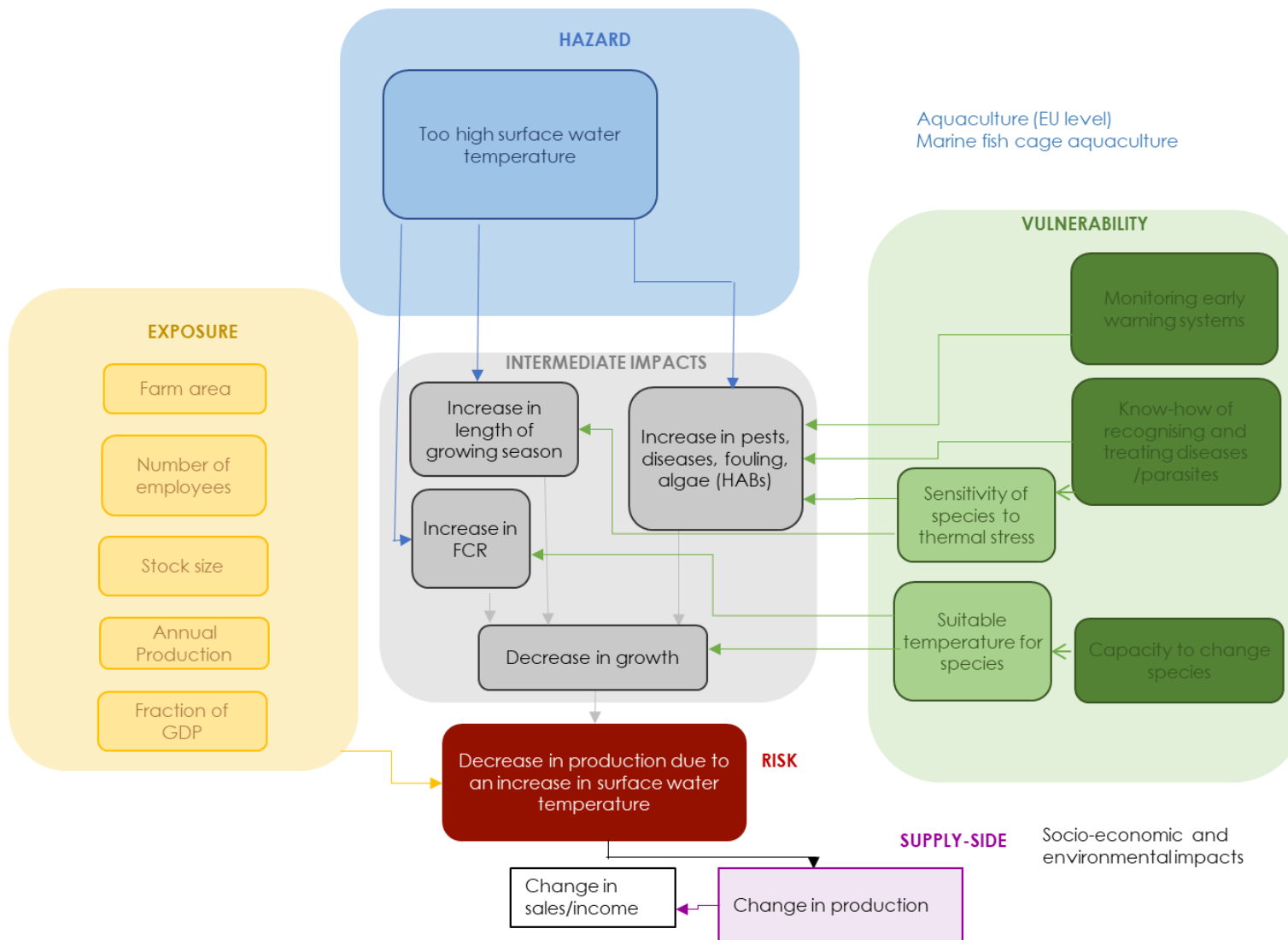


FIGURE 17: 1-DECREASE IN PRODUCTION DUE TO AN INCREASE IN SURFACE WATER TEMPERATURE

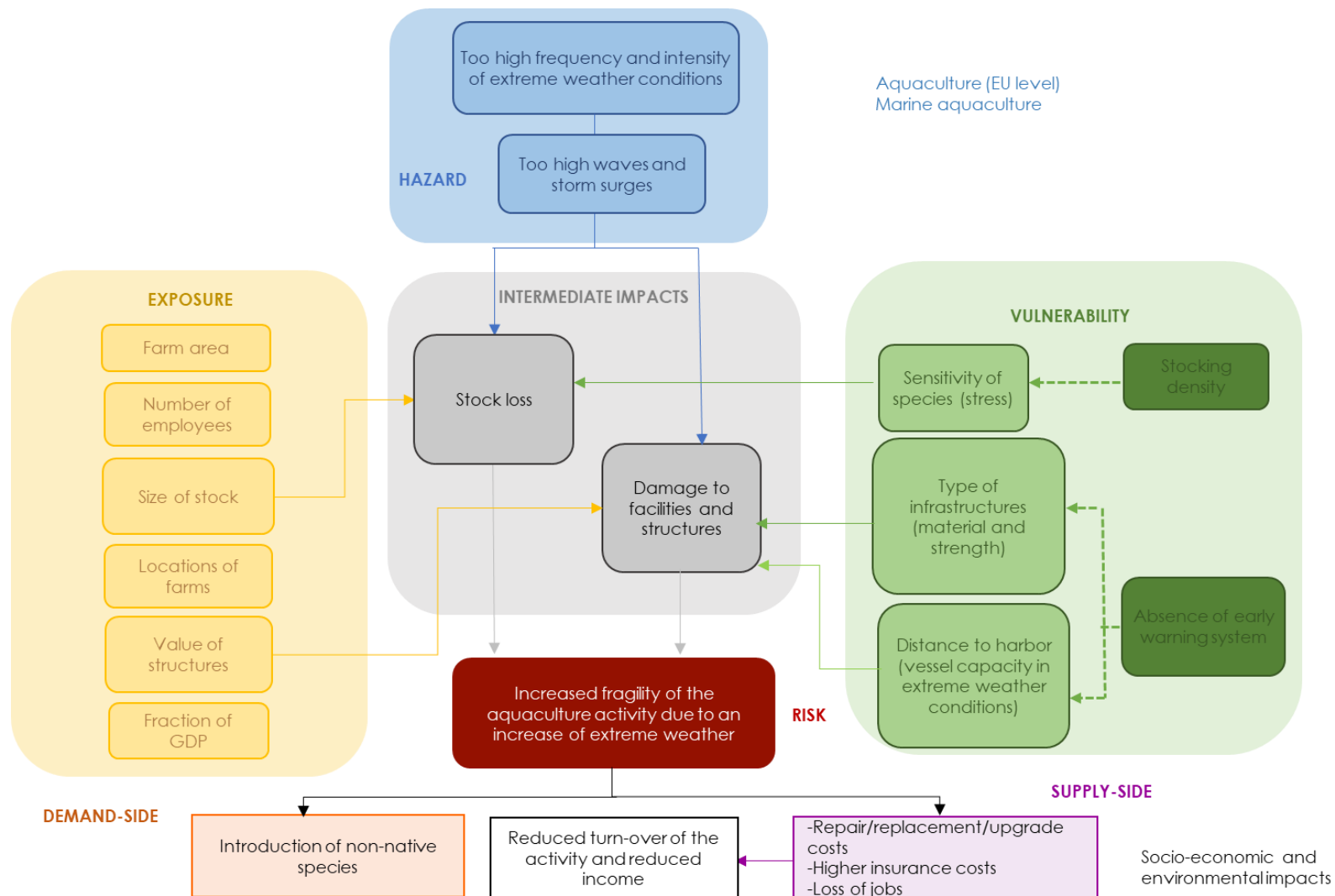


FIGURE 18: 1- INCREASED FRAGILITY OF THE AQUACULTURE ACTIVITY DUE TO EXTREME EVENTS

4.3. Marine energy

The following IC have been selected for the marine energy (figure 20 to figure 22):

Risk of changes in power generation due to long term climate change and variability

Although the main issue is marine energy, the energy group proposed to include also on-land power generation by RES (Renewable Energy Sources) and conventional fossil systems, in the risk IC analysis. The reason is that on land fossil power generation for back-up of marine RES generation will also be impacted by climate change.

Risk of changes in energy demand due to changes in precipitations and temperatures

In the island electrical context, instantaneous balancing of the island electrical system is one of the main challenges of the System Operator, especially in scenarios of high marine RES generation. Disposing of non-critical manageable loads like water desalination units contribute, from the Demand Side, to compensate the variability and fluctuation of non-dispatchable RES generation. From the demand side, climate change will also have important negative impacts on increase on energy demand, especially from water desalination systems in islands (higher water demand from all exposure economic sectors, including residential, and from higher air-conditioning demand to maintain comfort conditions, especially in islands with high tourist activity).

Risk of damages to transmission grids due to extreme events

Power generated by marine RES systems will have to be fed into the island electrical systems, to be consumed by island electrical systems. Therefore, the protection of on-land electrical infrastructures is fundamental to assure that marine energy systems can work. Adaptation to climate change risk has therefore to include off-shore and on-land island electrical infrastructures. All factors related to Exposures and Vulnerability affecting on-land transmission and distribution infrastructures therefore have also been included in the risk analysis.

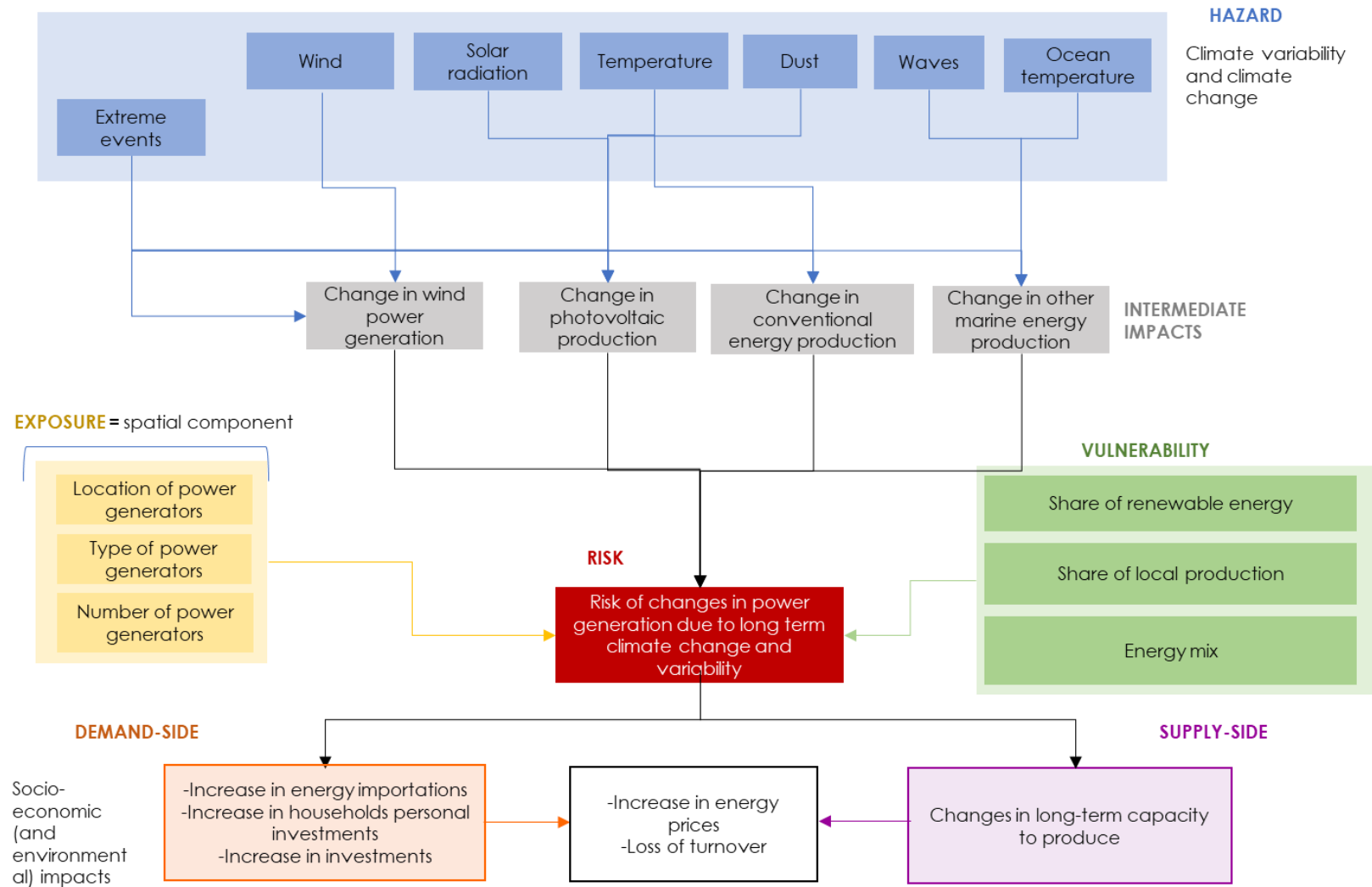


FIGURE 19: 1-RISK OF CHANGES IN POWER GENERATION DUE TO LONG TERM CLIMATE CHANGE AND VARIABILITY

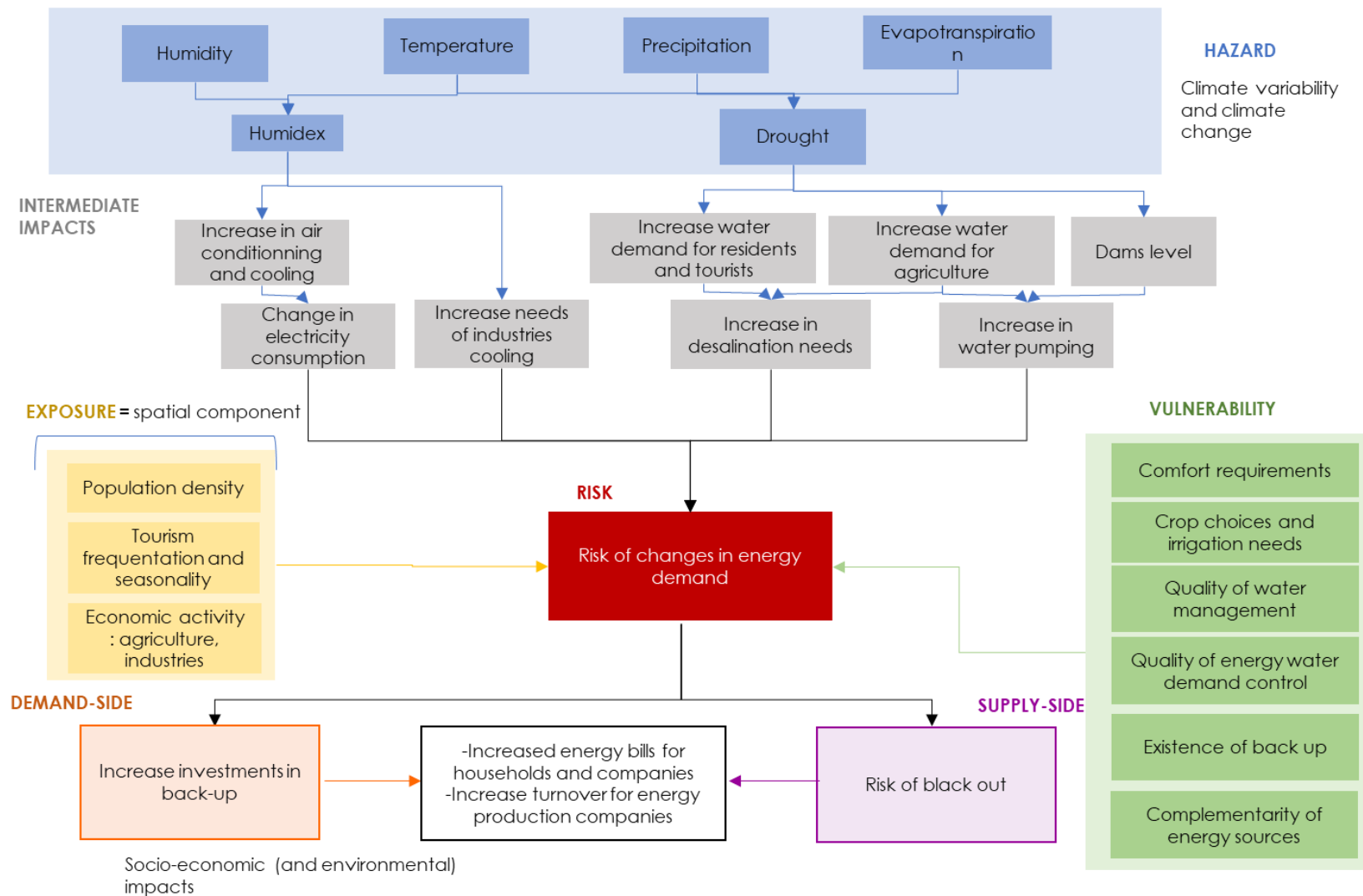


FIGURE 20: 2-RISK OF CHANGES IN ENERGY DEMAND DUE TO CHANGES IN PRECIPITATIONS AND TEMPERATURES



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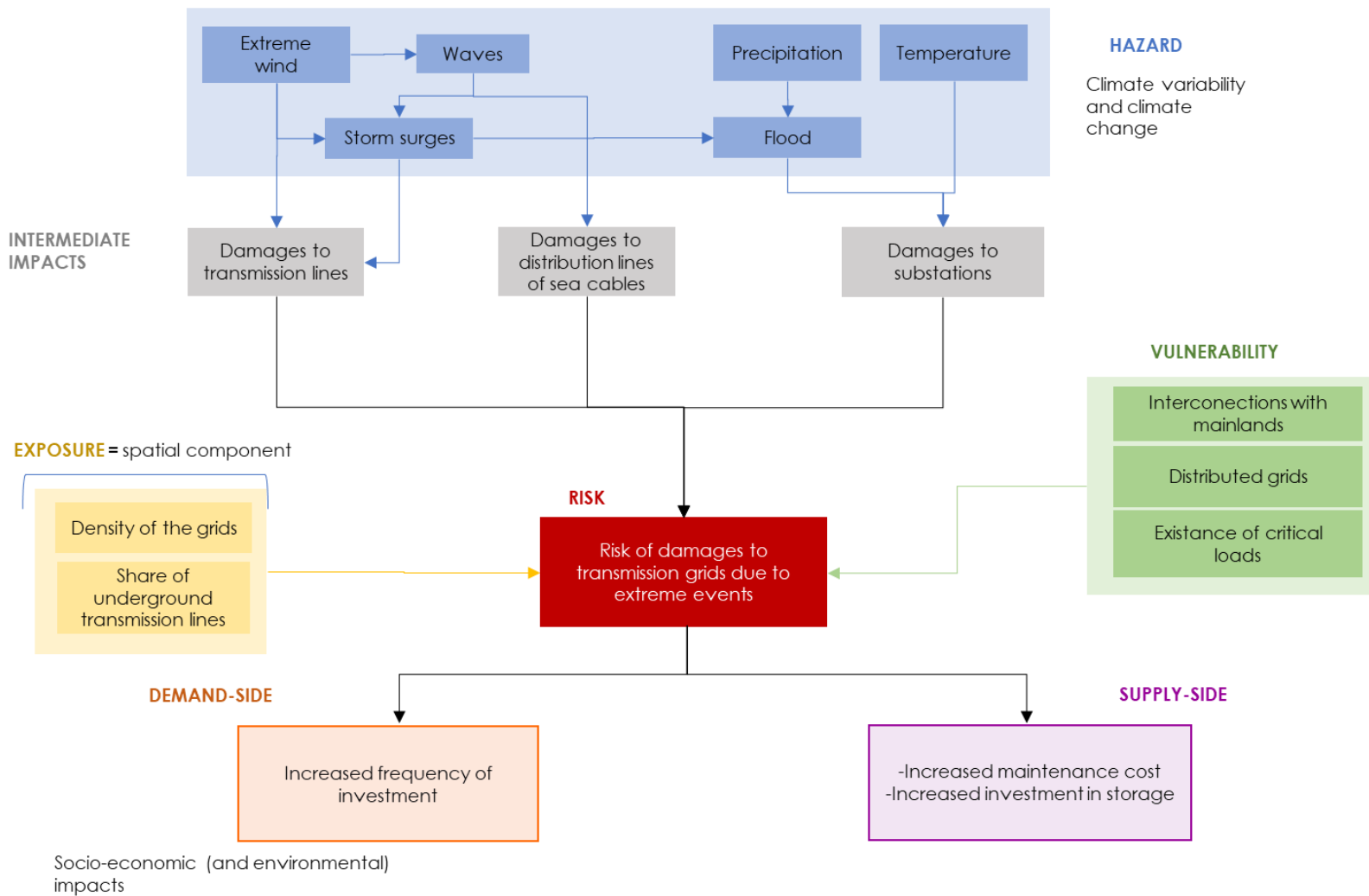


FIGURE 21: 3- RISK OF DAMAGES TO TRANSMISSION GRIDS DUE TO EXTREME EVENTS

4.4. Maritime transport

The following three impacts chains have been developed for the maritime transport sector (figure 23 to figure 25):

Risk of damages to ports' infrastructures and equipment due to floods and waves

The infrastructures and equipment of the ports are vulnerable to climatic hazards, like the rising of sea level and extreme weather events. In the past, these events have caused floods in the ports and their temporary closure.

For this reason, the elements that are exposed to this risk are the ports, the ships, the passengers and goods transported, as well as the population of the island, as their chances to travel are limited. This leads to another risk, the isolation due to transport disruption. However, some factors would mitigate the impact of climatic events. Some of these are the knowledge or training applied to the sector, or the existence of an early warning system.

The risk would have socio-economic impacts, both from the demand and the supply sides, which would result in a less turnover from maritime transport activities.

Risk of damages to ships on route (open water and near coast) due to extreme weather events

The ships, whether anchored or moored, are vulnerable to climatic hazards. Waves height and intensity, as well as their direction have caused losses in the past. The routes and the nature of the transport are elements exposed to these damages, as some islands are part of important transoceanic routes.

The good condition of the ships is a significant factor, as those well prepared could cope with the extreme weather events. Also, the knowledge and training, the early warning systems and the risk management plans are factors that could help in the mitigation of the hazards' consequences.

In this case, there are socio-economic impacts from the demand and the supply sides. They lead to less turnover from maritime transport activities.

Risk of isolation due to transport disruption

This IC represents the consequence of the two previous ICs. Due to extreme weather events, the population would be at risk of isolation.

The elements exposed in the IC are like the previous IC's exposure components. The location of ports and their number, the passengers and the goods transported, as well as the population of the islands are vulnerable. Some factors represent the vulnerability of this risk. The island dependence on maritime transport, the quality of the infrastructures or the harbour alternatives are factors that show the vulnerability of the sector to cope with these problems.

As in the previous IC, there are socio-economic impacts from the demand and the supply sides. The problems are related to the inconvenience for inhabitants and the disruption and isolation of the islands.

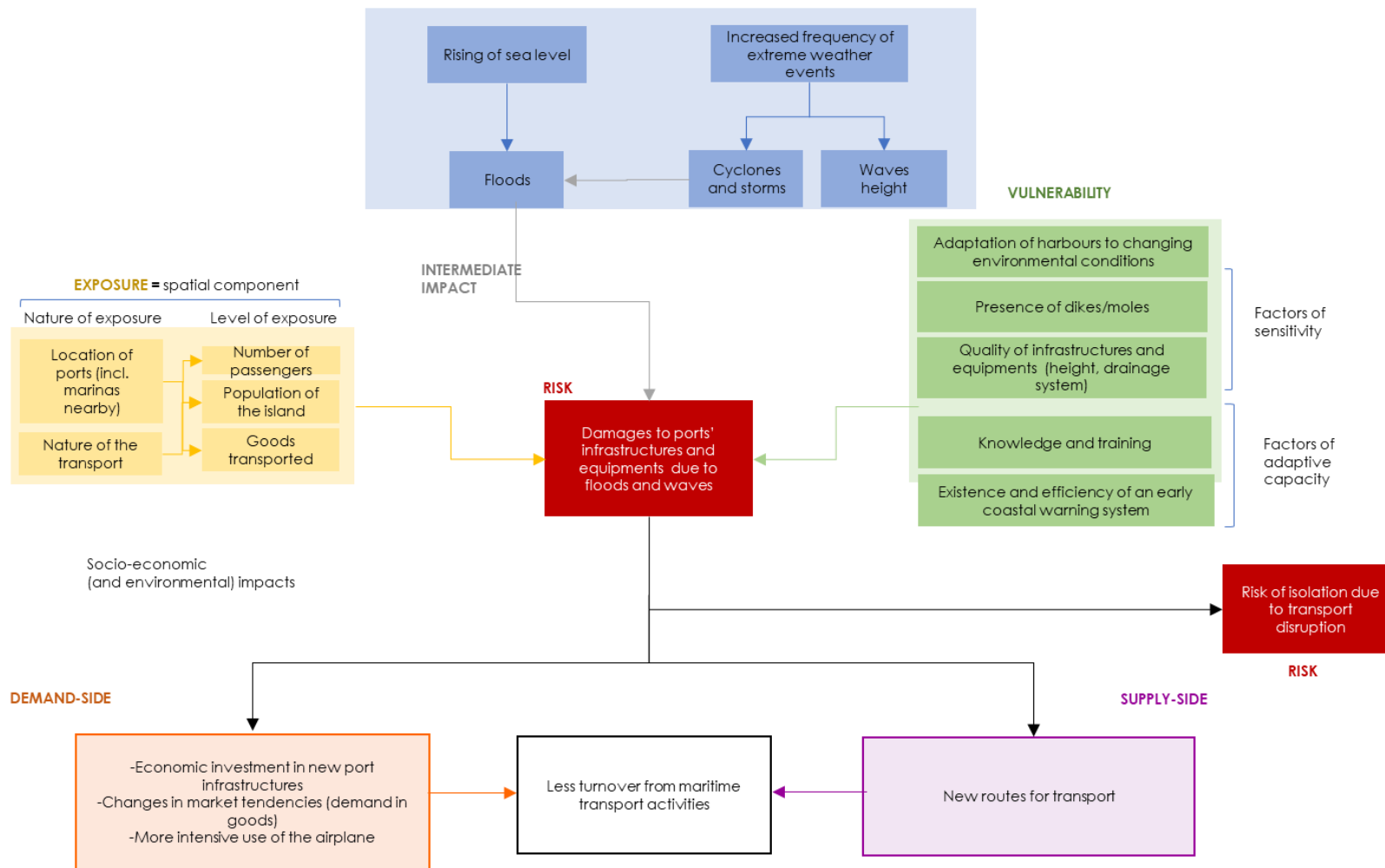


FIGURE 22: 1-RISK OF DAMAGES IN PORT INFRASTRUCTURES

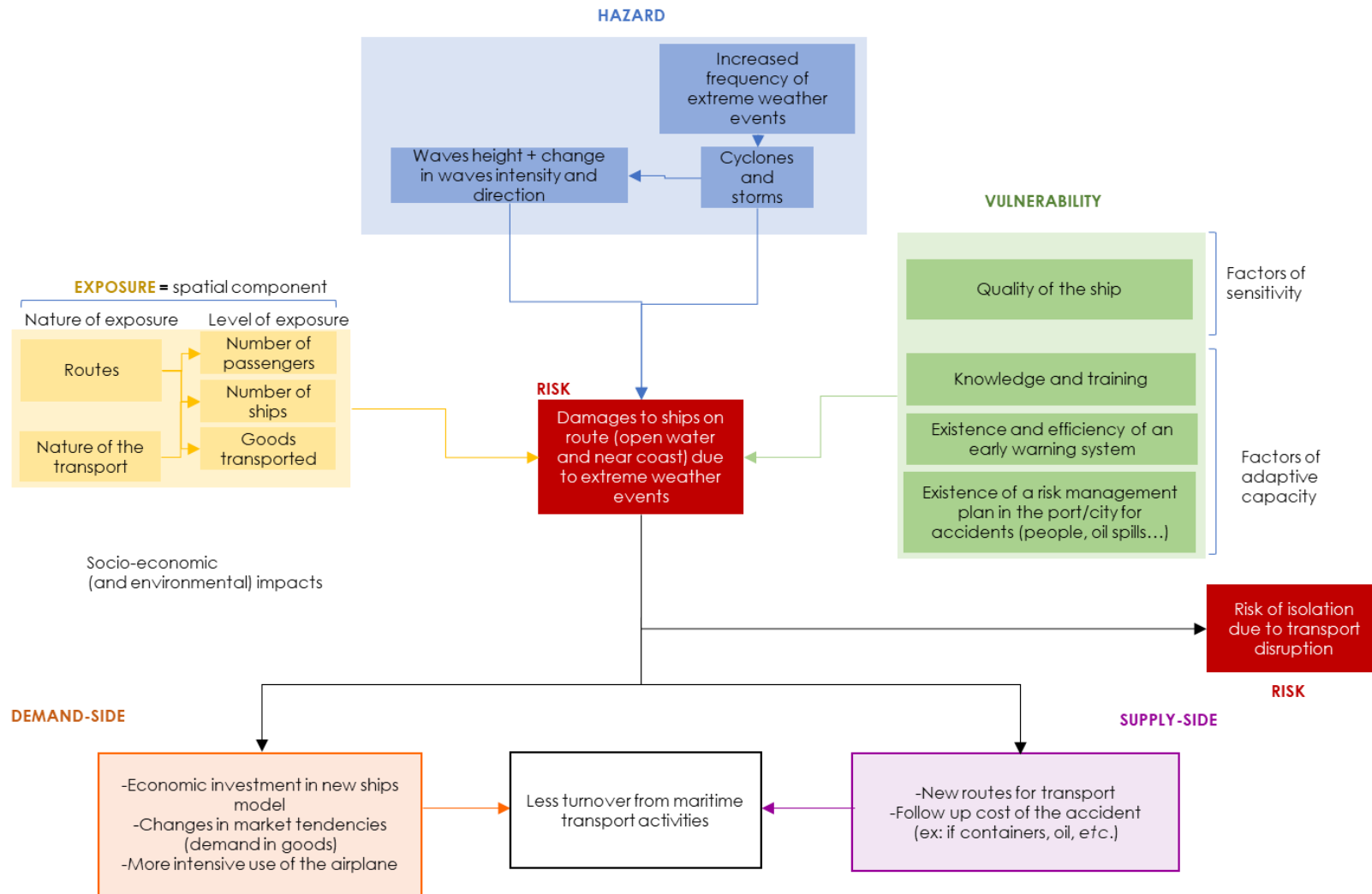


FIGURE 23: 2- Damages to ships on route

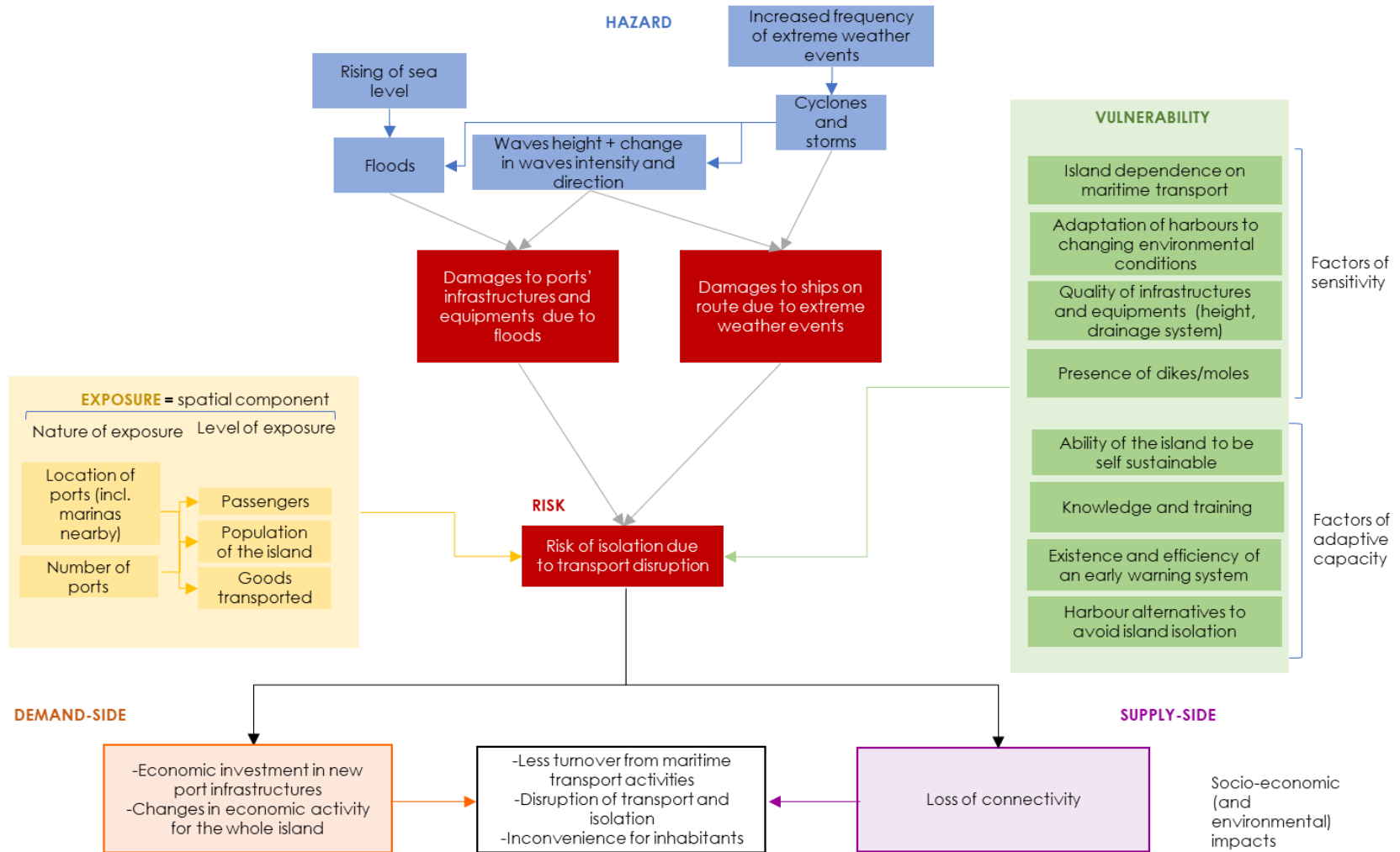


FIGURE 24: 3- RISK OF TRANSPORT DISRUPTION

5. Conclusion

This deliverable presents 17 impacts chains detailed for the 4 sectors:

- 9 impact chains for maritime and coastal tourism,
- 3 for marine energy,
- 3 for maritime transport,
- and 2 for aquaculture.

Within D3.3, indicators will be set up by the CMCC with the help of the sector leaders and the IFPs before replacing each theoretical component of the risk with indicators commonly used in the scientific publications or projects on climate change from a typology of indicators that will allow WP4 to identify climate data (4.1) but also to assign to each modelling WPs (WP4, 5 and 6) the parameters to be modelled.

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7. Appendix 1

Effect of Risks (IC) on Demand and Supply

The various Risks considered in the Impact Chains (IC) will impact different socio-economic variables. These impacts can be distinguished depending on whether they directly affect the demand side or the supply side, by shifting them (or affecting the slope of these curves, if the price elasticity of the demand or of the supply are affected). Apart from this *direct effect*, the impacts could produce externalities (either positive or negative), which will affect the price and quantity exchanged in equilibrium (for instance, in the negative externality the private cost is lower than social cost; so the quantity produced in equilibrium is higher than the optimal one). The effects produced by the externalities can be modelled by shifting the demand or the supply (or by shifting their slope if it is considered as a tax). Moreover, spillover effects over other sectors could also be produced.

An example is considered to illustrate the previous concepts. We will consider the IC in which the beach surface is reduced due to the sea-level rise and extreme oceanic conditions. These hazards consequently produce coastal erosion and coastal inundation, which ultimately translate into beach surface reduction. The following graph (Figure 1) represents the beach demand and supply.

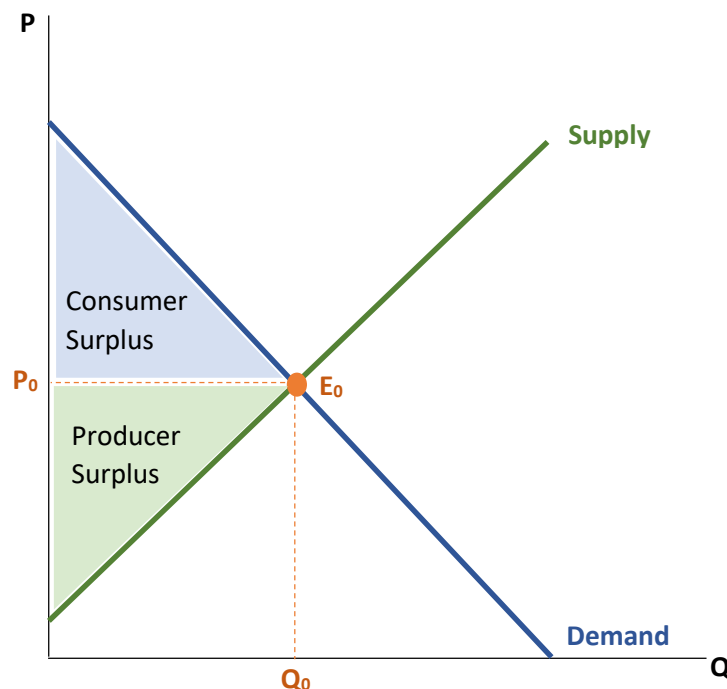


Figure 1. Interaction of the demand and the supply curves.

Note that the price and quantity of equilibrium are determined by the interaction of the demand and the supply curves. In this example, P_0 and Q_0 represent the price and quantity of equilibrium. For each quantity, the demand represents the willingness to pay for that quantity of good, while the supply curve represents the price the producer is willing to accept. Therefore, the area below the demand curve and above the equilibrium price represents the consumer surplus (the difference between the willingness to pay for each quantity of good to the left of Q_0 and the market price finally payed). Similarly, the area above the supply curve, up to the market price, represents the producer surplus.

Starting from the equilibrium E_0 of beach demand and supply, we can analyze how a reduction in the beach surface, due to climate change, affects the market.

Scenario 1: No policy response. We first consider the framework in which the demand is affected, but the supply is not affected (there is no policy response in the sense that no action is taken to mitigate the impact).

Effect on demand: If the aesthetics of the coast are reduced, then tourists will be less willing to pay for the good. This produces a shift of the demand curve to the left. Now the quantity of good demanded at each price is reduced. Given that the supply is not affected, we will see an impact on beach-based tourism and on prices (Figure 2). A new equilibrium is attained (E_1), in which both the equilibrium price and quantity are reduced.

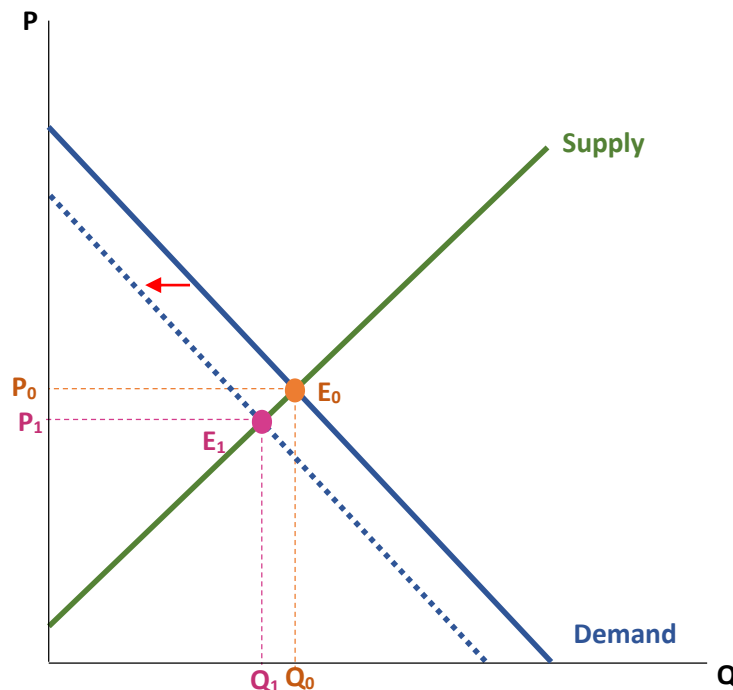


Figure 2. Shift of the demand curve to the left.

Note that a shift in the demand curve results in a greater relative change in the equilibrium price or the equilibrium quantity depending on the shape of the supply curve. This idea will be explained in detail in the next scenario.

Scenario 2: Policy response. Now assume that the demand is not affected because a great effort is made in order to preserve the beach surface at the original level, after the climate change. This means that the protection costs are high. Effect on supply: increase in maintenance and protection cost.

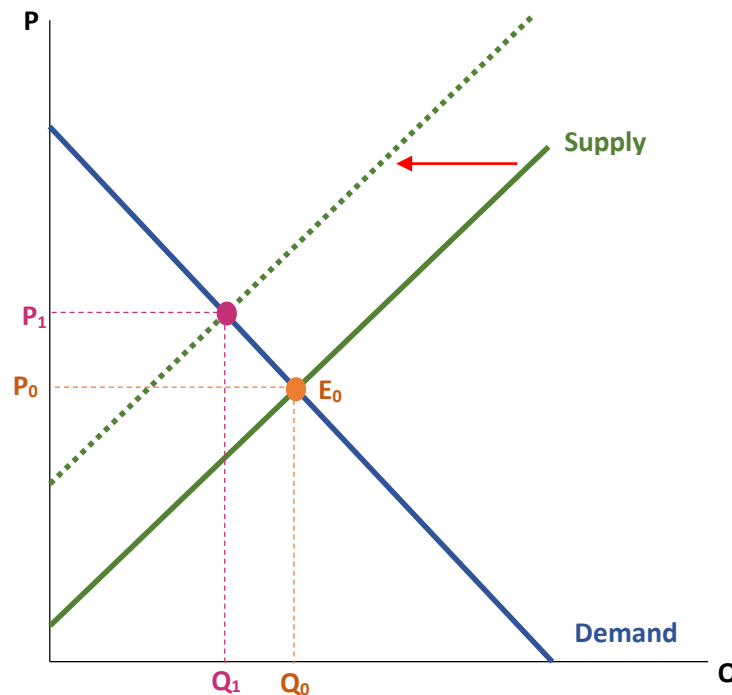


Figure 3. Shift of the supply curve to the left.

It can be seen in the graph (Figure 3) that a new equilibrium is attained (E_1). When the supply is shifted to the left, a lower quantity is produced in the new equilibrium, while the equilibrium price is increased.

As it was hinted before (in the case of a demand shift), the relative effect on equilibrium price and quantity depends on the elasticity of the demand and/or of the supply curve. In the context in which the supply curve is affected, if the demand curve is fairly elastic (flat), a shift in the supply curve will change the equilibrium quantity relatively more than the equilibrium price. If the demand curve is more inelastic (vertical), a shift in the supply curve will change the equilibrium price relatively more than the equilibrium quantity.

Example: Consider two destinations (A and B) facing two different demands (the demand of destination A is more elastic, this is, it is more sensitive to price changes), which are affected by the same shock to the supply curve.

It can be seen in the following graph (Figure 4) how the equilibrium prices and quantities are affected depending on the elasticities of the demand. The demand of destination A is more elastic (more sensitive to prices), so a shift in the supply curve changes the equilibrium quantity relatively more than the prices. However, the demand of destination B is more inelastic, meaning that the quantity exchanged in equilibrium changes relatively less than the changes in prices. It can be seen that a shock to the supply curve affects the equilibrium prices of destination B much more than the equilibrium quantities of destination B.

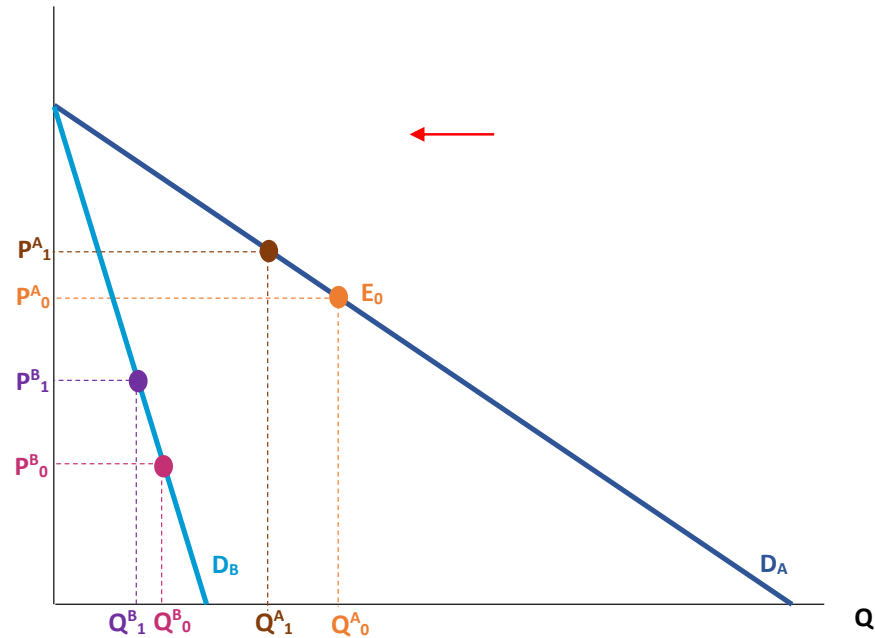


Figure 4. Shift of the supply curve to the left. Demands of destination A and B considered.

Scenario 3. Demand and Supply are affected. Effect on demand: If the aesthetics of the coast are reduced, then tourists will be less willing to pay for the good. Effect on supply: increased costs of maintenance. In this setting the relative effects on equilibrium prices and quantities (which is more affected) depend on the relative elasticities of both the demand curve and the supply curve.

It can be seen in the graph (Figure 5) that a new equilibrium is attained (E_1). While the quantity in equilibrium will always be reduced, the new price could be higher, lower or the same as the initial one, depending on the elasticities of demand and supply curves and on the size of the shifts. It should also be remarked that the consumer and producer surplus are both reduced due to the impact.

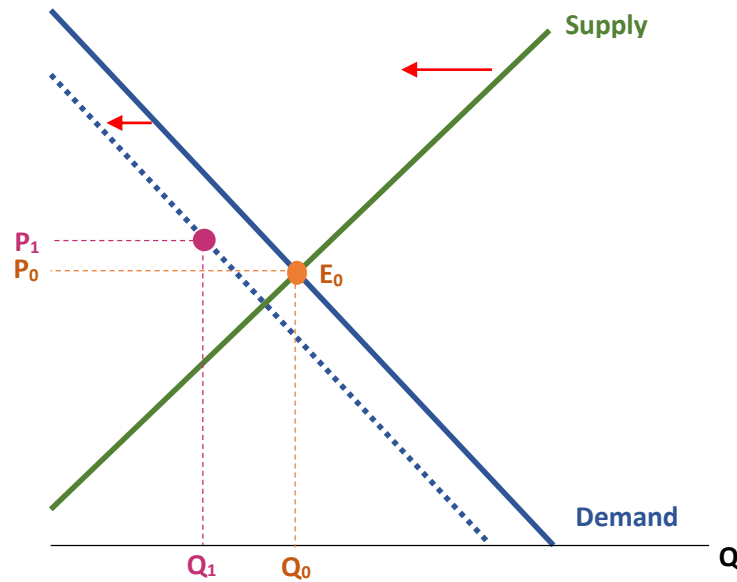


Figure 5. Shift of the demand and the supply curves to the left.

When studying the IC, most of the impacts that could be considered could be classified as a shock to the demand curve or as a shock to the supply curve. The final results will translate, in most of the cases, in a reduction in tourists' arrivals (lower quantity in equilibrium) and in changes in equilibrium prices. Consequently, changes in tourists' expenditures and changes in producers' income will be produced. Thus, the analysis of the new price and quantity in equilibrium summarizes many potential effects and will be the main parameters of interest in the estimations (how prices and quantities change). These parameters then allow for the possibility of computing other relevant variables (for instance, tourists' expenses or producers' income). Therefore, the impacts produced by the risks included in the general ICs could be considered as illustrative, while the final or relevant impacts to the demand or supply side ultimately considered could depend on the data availability.

8. Appendix 2



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WP3 Questionnaire Aquaculture Sector for Island Focal Points

In order to get an overview of the aquaculture sector on the different islands and to select islands suitable for case studies for this sector, we would like to ask you to provide as much information for each of the questions as possible. If the question is not applicable to your island write N/A and if there is no data available write NDA. You may also provide an estimation, in this case please add estimated behind the number. Thank you very much!!

1. General Information

- 1.1 Name:
- 1.2 Institution:
- 1.3 Island (group):

2. Size of the industry

- 2.1 What is the number of active aquaculture companies (marine only) on your island(s)?
- 2.2 What is the number of other aquaculture companies (fresh water and land based) on your island(s)?
- 2.3 How many people are employed in the aquaculture sector on your island(s)?
- 2.4 What is the annual production in kilo and in Euro on your island(s)? If available present latest number as well as historic numbers.
- 2.5 Are there any incentives/funding provided for the sector by the government?
- 2.6 Are there any large investments planned to increase the size of the sector?

3. Characteristics of the sector

- 3.1 What types of aquaculture (Offshore, cage, coastal etc.) can be found on your island(s)?
If possible, include proximity to island.
- 3.2 What is the main type of aquaculture?
- 3.3 What species are cultured (include fish, crustaceans, shell fish, and aquatic plants)?
-Main species:
-Other species:

4. Impact of Climate Change

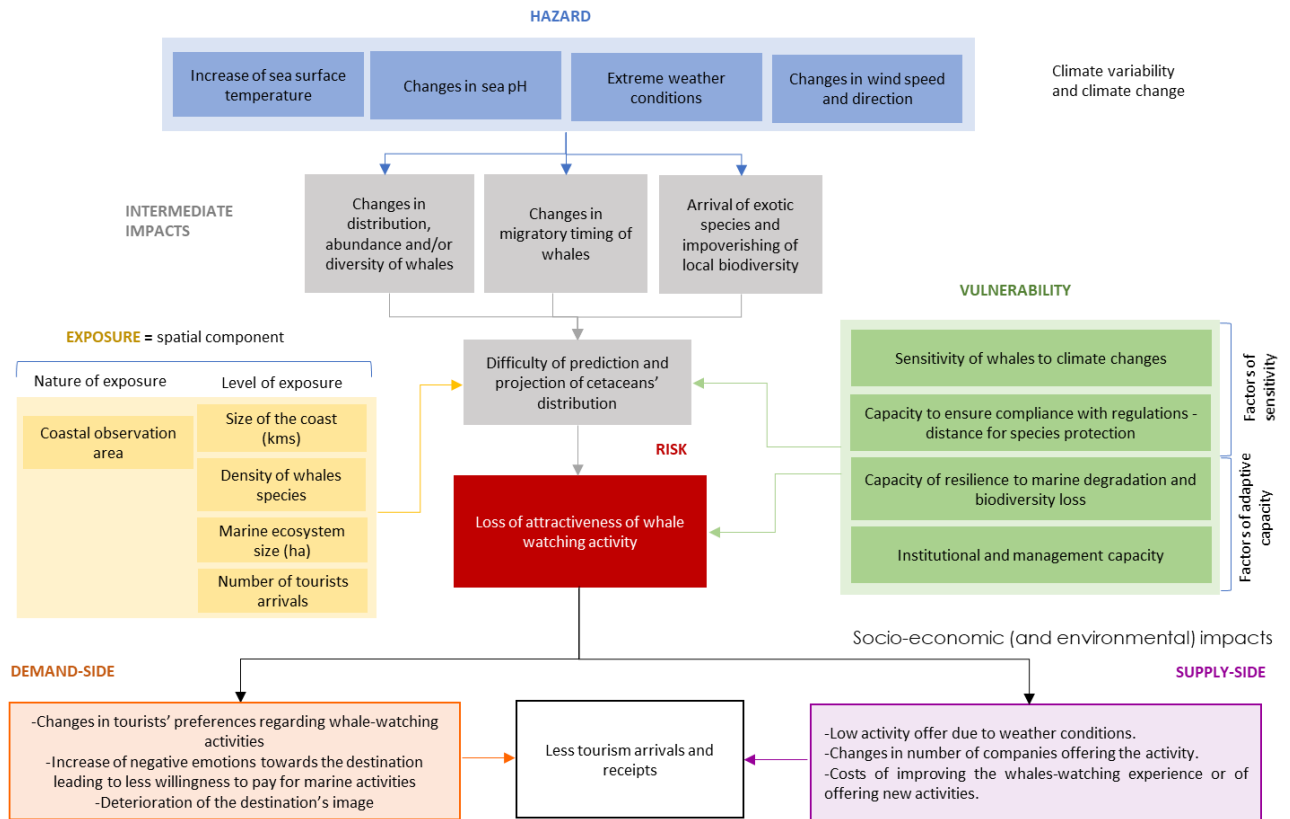
- 4.1 Are the aquaculture operations located in areas protected against waves/storm (bays) or in the open sea?
- 4.2 Are there changes in weather conditions that affect the sector observed over the last 5-10 years? (e.g increase in frequency and intensity of storms, water temperature change, occurrence or increased occurrence of algal blooms etc.)
- 4.3 Did the aquaculture operators experience any damages or loss to stock over the past 5-10 years?
- 4.4 If yes, were these damages or stock losses attributed to climate change (extreme weather events, increased temperature or algal blooms etc.)?
- 4.5 Did the aquaculture operators experience any positive effects (increased growth, increased food conversion ratios, prolonged growing season) due to climate change (increase in sea water temperature, change in currents etc.)
- 4.6 Do you know of any efforts or future developments to protect aquaculture operations from climate change impacts (e.g. storms, water temperature, algal blooms etc)? If yes, is there a timeline for implementation?

5. Specific issues

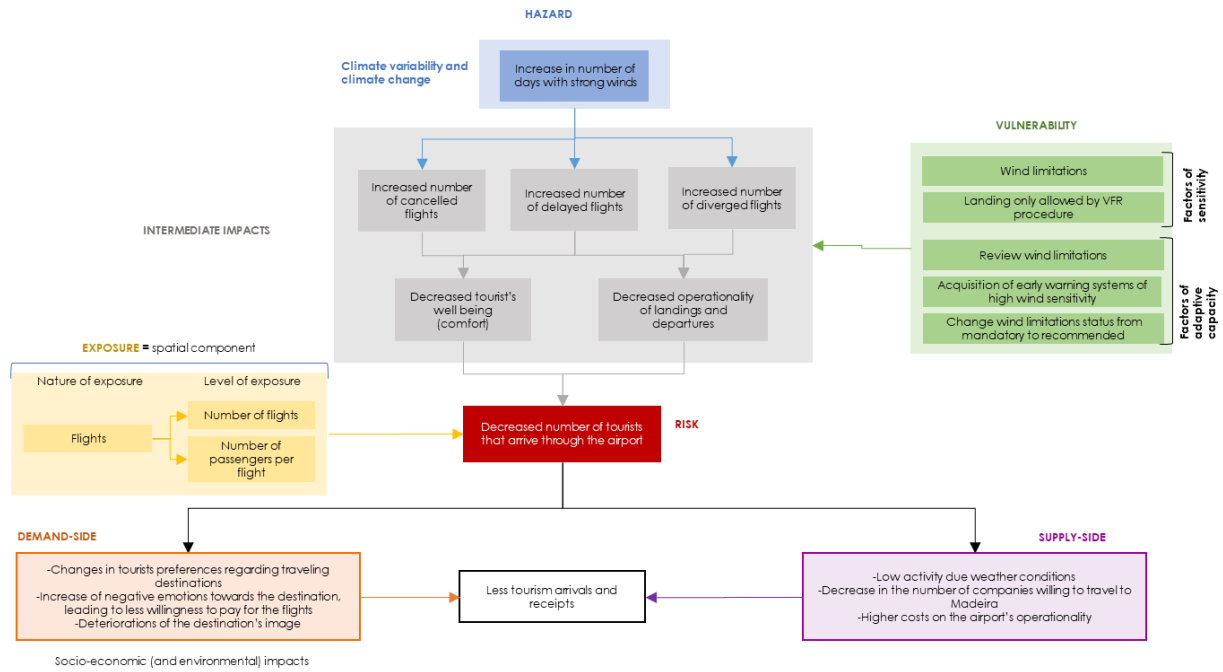
- 5.1 Are there any specific issues on your island(s) regarding aquaculture? If yes, please describe the problem and solutions implemented if any.
- 5.2 Are aquaculture operators in your island receptive to researchers and/or would they offer their opinion on related climate change matters?

9. Appendix 3

Case study: Loss of attractiveness of touristic marine environments: Whale-Watching – Azores Islands



Case study: 3- Loss of tourist experience value in the destination due to the quality of infrastructure and facilities- Madeira's airport



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2020 research and innovation programme under Grant Agreement
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