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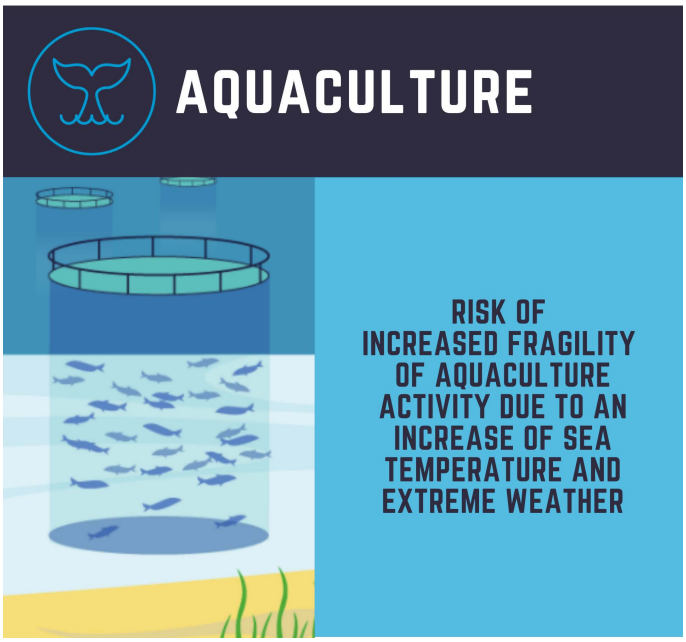

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Loss of attractiveness due to increased danger of forest fires in touristic areas

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Forest fires are considered an important parameter for the attractiveness of tourist destinations, especially in the Mediterranean area. Severe episodes were met in Algarve (Portugal) and Greece (Athens area) in the recent period, threatening the tourist season. The concept of Impact Chain (Fritzsche et al. 2014) is applied as a climate risk assessment method, and is considered an ideal tool to communicate to stakeholders the complex relations between climate hazards and socio economic effects on sectorial activities (Schneiderbauer et al. 2013).

The Impact Chains propose diagrams articulating the causal links between the different components of climate risks (according to AR5 concepts: hazards, exposure, vulnerability, risks). For each of these components, several indicators are selected and collected. Data are then normalised to be able to be aggregated with different weights. The final objective is to achieve a standardised risk score that, according to the spatial scale of the analysis can allow comparison and decision making on adaptation, including hierarchization of resource allocation or identification of adaptation options to mitigate climate risk.

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

- The selection of "priority impacts" with the sector teams;
- The identification of risks with the sector teams and Islands Focal Points (IFPs) and the construction of theoretical impact chains, filling the components and identifying the factors inside the different risk components, with the sector teams for the generic IC and with the IFPs for the specific IC;
- The identification and selection of the indicators for each factor of risk in the various impact chains, according to a number of characteristics and criteria, with the help of the sector leaders and the IFPs to replace theoretical component of the risk with indicators commonly used in the scientific publications or projects on climate change.

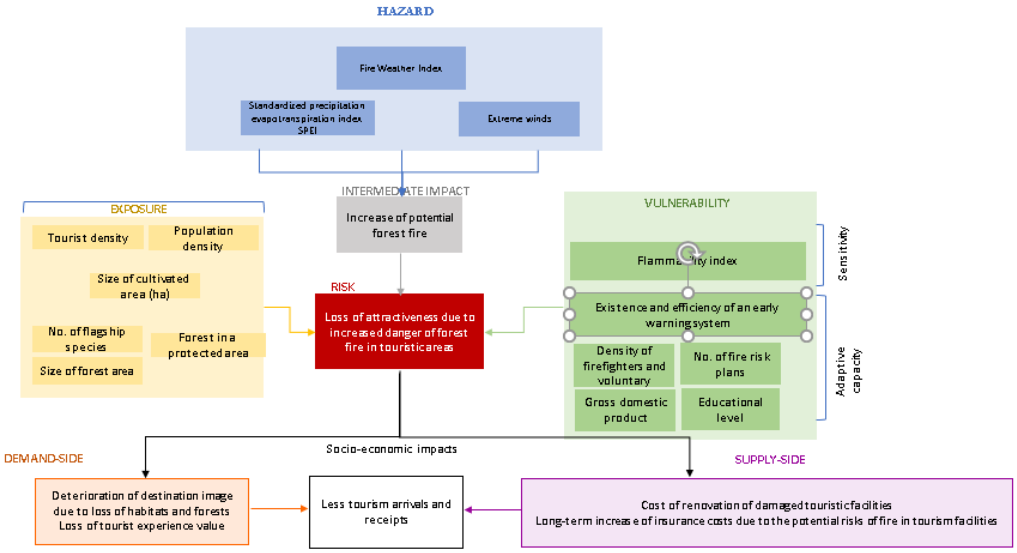

Figure 1: Theoretical IC - Loss of attractiveness due to increased danger of forest fire in touristic areas
Source: Soclimpact deliverable D3.2

After defining the theoretical design, the identification and selection of suitable indicators were associated to each factor of the impact chain and a new diagram tool has been proposed.

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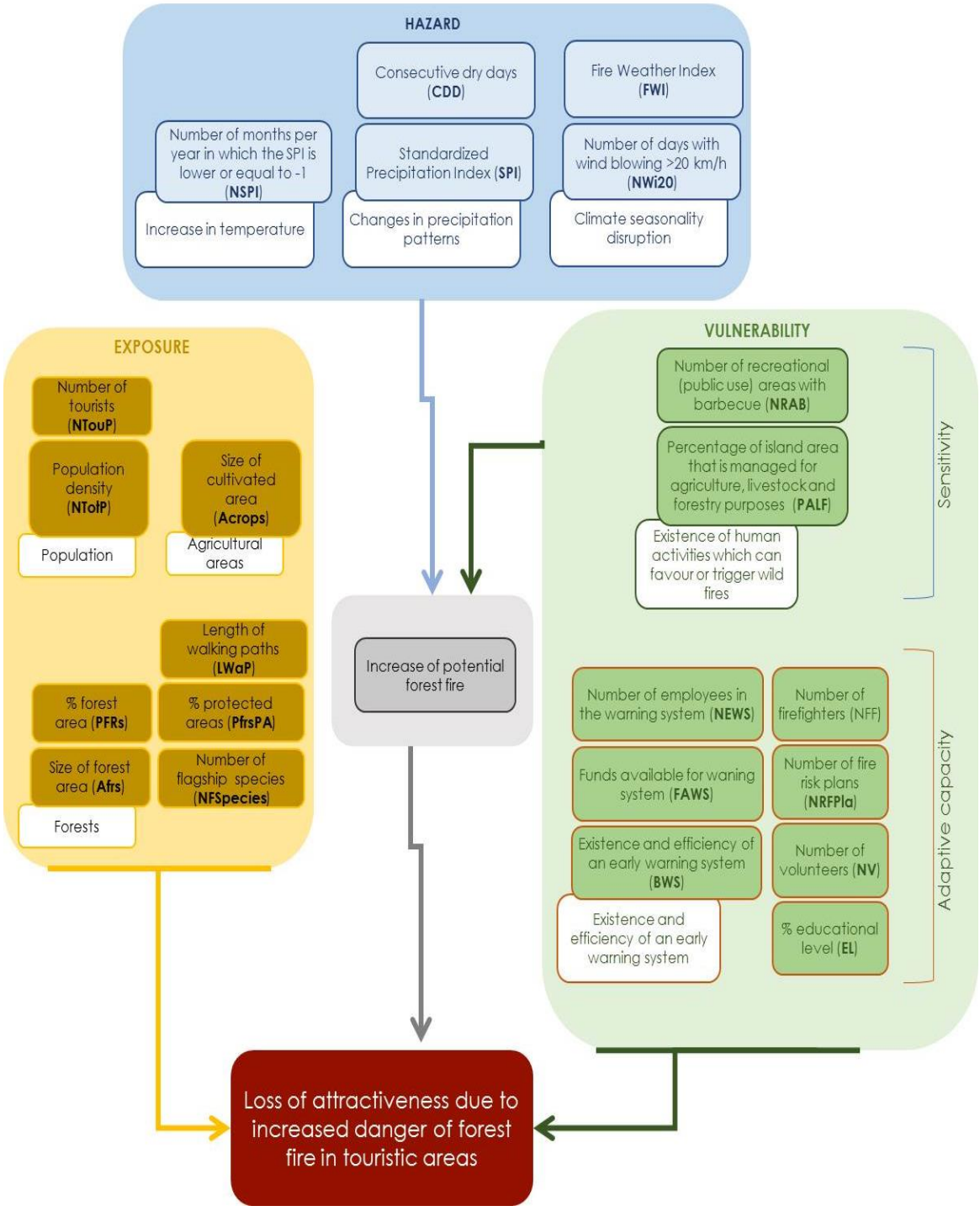

Figure 2: Loss of attractiveness due to increased danger of forest fire in touristic areas
Source: Soclimpact deliverable D3.3

For the operationalization, we assessed whether selected indicators are sufficiently explicit or not. Indeed, many indicators were formulated in a very broad way, causing a few problems in identifying suitable data sets. Furthermore, the data were checked for explicit spatial coverage,

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resolution, temporal coverage and time frame. Finally, we evaluated possible substitutes or alternatives for those indicators with no suitable data to substantiate them.

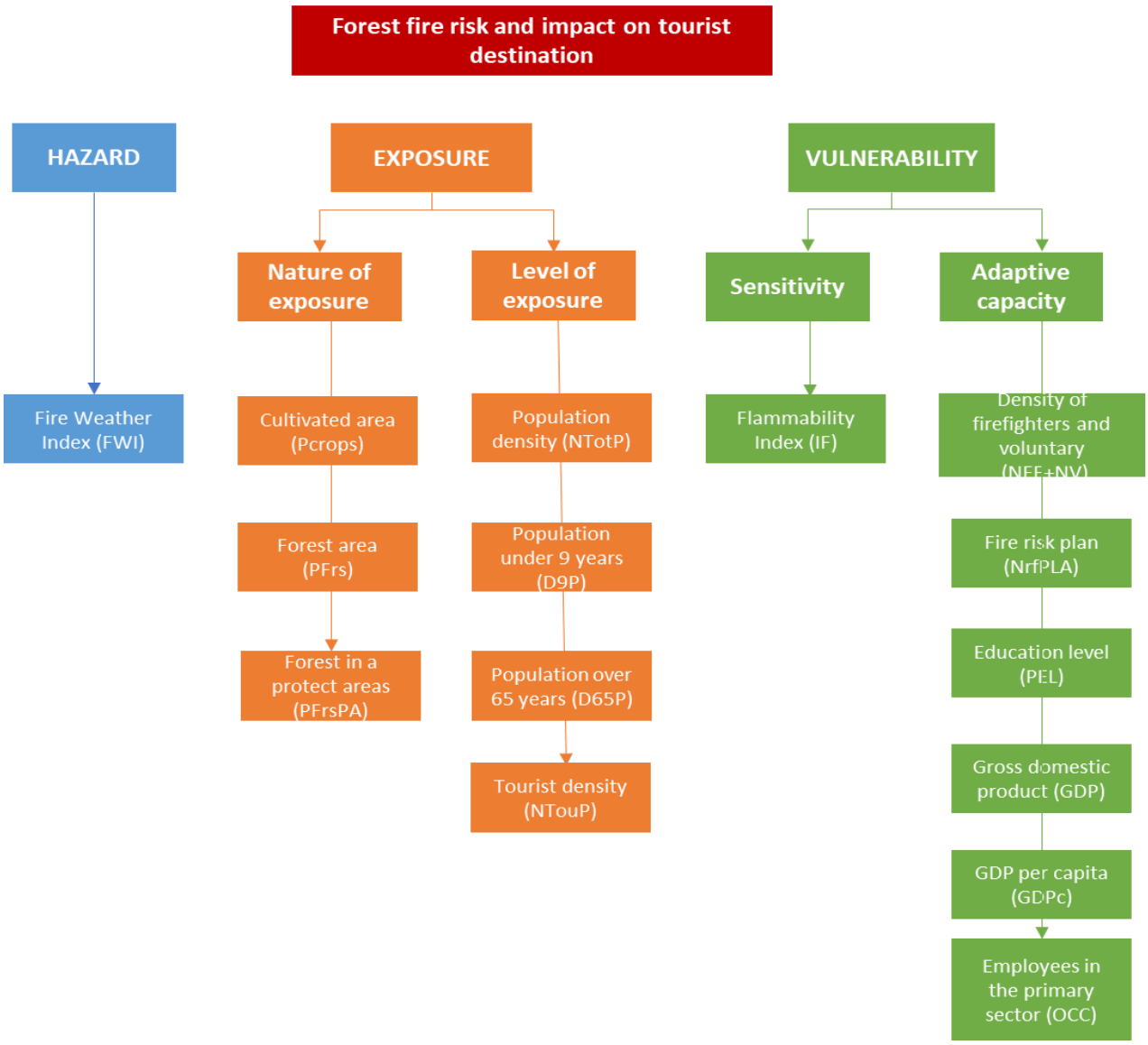

Figure 3: Final Impact Chain Model
Source: Soclimpact deliverable D4.5

For the Azores islands, which are not included or are included marginally in the EURO and MENA-CORDEX domains, the ESCENA Project model runs (Jiménez-Guerrero et al. 2013) were employed. They have been produced under the AR4 IPCC scenarios with 25 km spatial resolution. Here, SRES B1 and A1B scenarios are selected, considered to be closer to RCP2.6 and RCP8.5, respectively.

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The historical period (reference) is 1981-2000 and the near future period is 2031-2050. The selected RCM/GCM pairs that were available are presented in the following table:

Table1: Climatic input variables and data sources for hazard component calculation for Azores

GCM/RCM pairs	Experiments
ECHAM5 r2/PROMES	Historical SRES A1B SRES B1
ARPEGE (version 3)/ PROMES	Historical SRES A1B SRES B1

Source: Soclimpact deliverable D4.5

In order to normalize the index, the min-max method was applied. Min-max normalizes indicators to have an identical range [0, 1] by subtracting the minimum value and dividing by the range of the indicator values (OECD 2008). Afterwards, the normalized index was categorized into five equal interval classes representing values from "Very low" to "Very high". With respect to Azores, as the models emission scenarios and future periods differ, the results are not comparable with the rest of the islands.

Considering the weighing, an assessment of GIZ methodology has been developed for this impact chain including interviews with various types of stakeholders (cf dedicated 4.5 to forest fires). Then, the risk score was calculated for the Azores separately from the other 9 islands as future data is not the same (for Azores, to compute the part of hazard (FWI), the scenario B1 and A1B have been used and for other islands RCP 2.6 and RCP 8.5).

Finally, in the calculation of risk, the exposure is the major component with 57% of the final score.

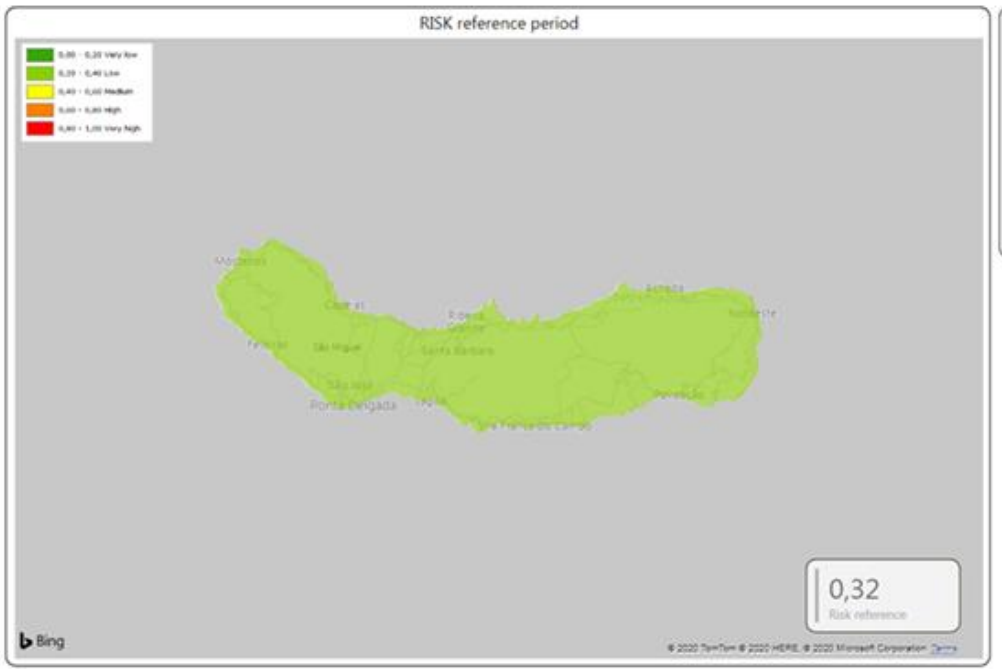

Figure 4: Risk score and components of the risk for the reference period
Source: SOCLIMPACT Deliverable Report – D4.5Comperhensive approach for policy makers

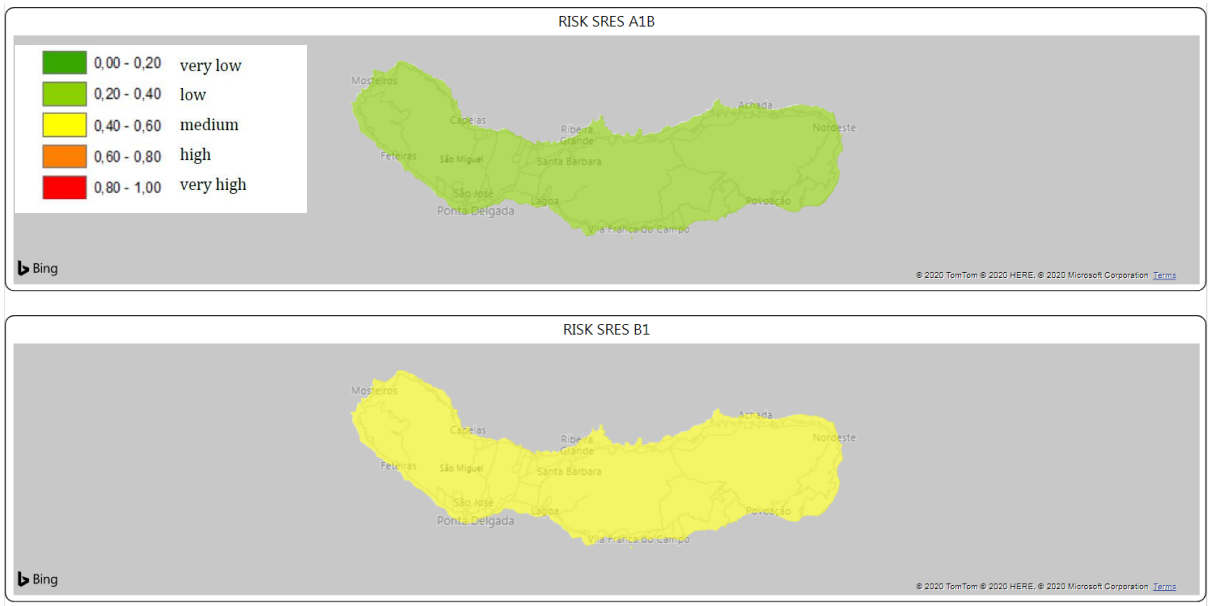

Figure 5: Risk score for scenarios for SRES B1 and A1B (near future)
Source: SOCLIMPACT Deliverable Report – D4.5Comperhensive approach for policy makers

The score of risk is low for Azores during the current period and for the near future under the scenario B1. Under the scenario B1, the risk will be medium.

Concerning the component of exposure in the calculation of the risk, the nature of exposure explains the majority of component with 75% and within the nature of exposure, the indicator "cultivated area" (%) is the most important in the sub-component.

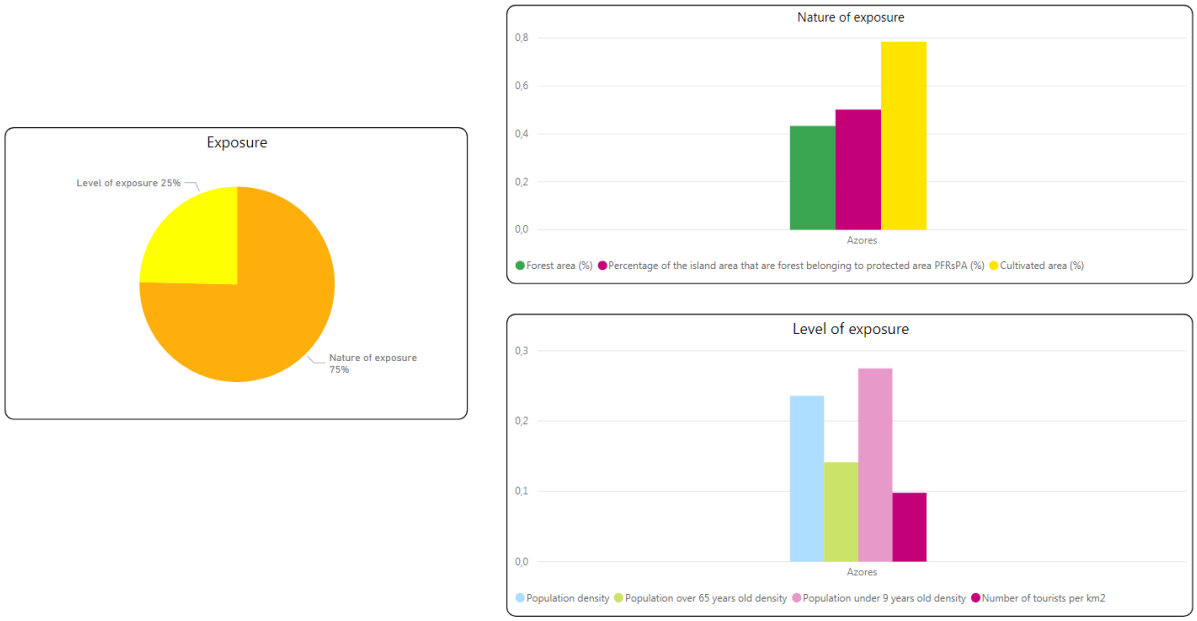

Figure 6: Details and scores of the two subcomponents of exposure (nature and level of exposure)
Source: SOCLIMPACT Deliverable Report – D4.5Comperhensive approach for policy makers

Concerning the vulnerability component, there is no current sensitivity with the flammability index and the component is only composed of adaptative capacity. The indicator about GDP is the most significant in the calculation of adaptative capacity.

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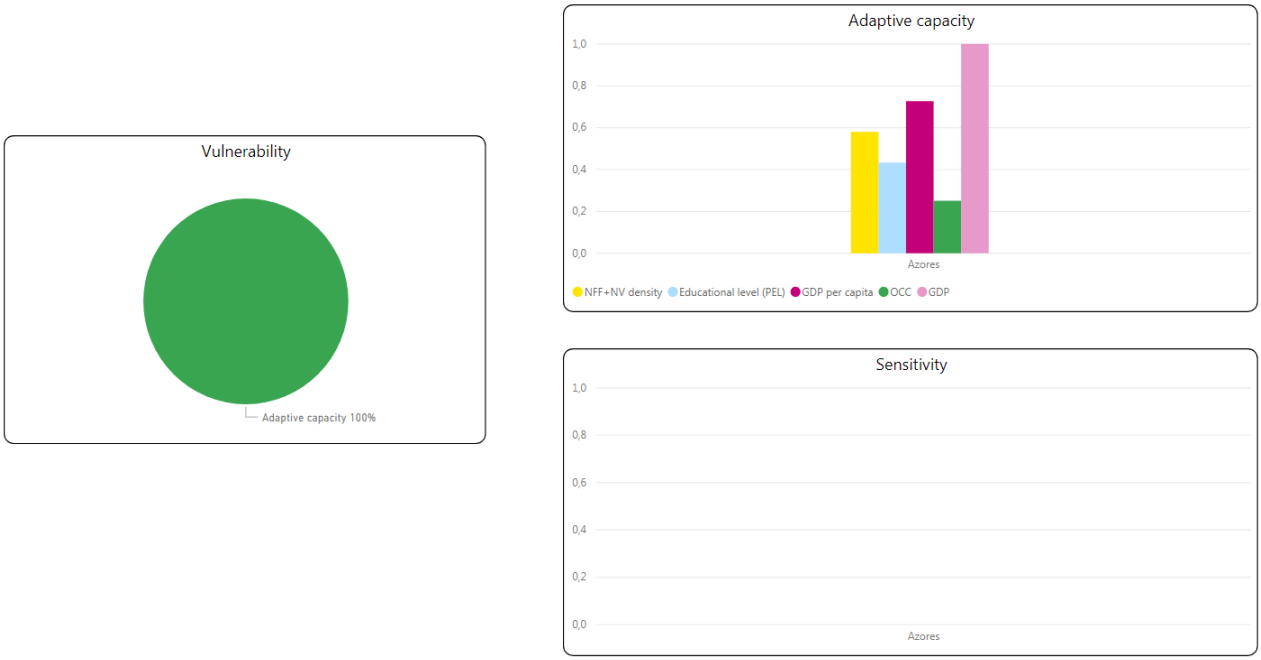

Figure 7: Details and scores of the two subcomponents of vulnerability (adaptative capacity and sensitivity)
Source: SOCLIMPACT Deliverable Report – D4.5Comperhensive approach for policy makers

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Increased fragility of aquaculture activity due to an increase of sea temperature and extreme weather

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In the Soclimpact project, aquaculture includes only marine-based operations where off-shore and coastal aquaculture are included, and freshwater and land-based aquaculture are excluded. Examples of climate change hazards that can impact aquaculture are changes in ocean warming and acidification, as well as oceoanographic changes in currents, waves, and wind speed. Sudden impacts such as an increase in the frequency and intensity of storms and heat waves are also impacting aquaculture. Other effects of climate change on aquaculture activities are increased invasions from alien species, increased spread of diseases and changes in the physiology of the cultivated species by changing temperature, oxygen availability and other important physical water parameters. An important indirect impact to aquaculture is the change in fisheries production due to climate change. Aquaculture of finfish is highly dependent on fisheries for feed ingredients. This already a current problem with many fisheries overexploited and will only intensify in the future. Climate change is also predicted to impact food safety, where temperature changes modify food safety risks associated with food production, storage, and distribution.

Socio-economic impacts on aquaculture are hard to assess due to the uncertainty of the changes in hazards and the limited knowledge these impacts have on the biophysical system of aquaculture species (Handisyde et al. 2014). In the framework of Soclimpact, the following risks were studied:

1) Risk of Fish species thermal stress due to increased sea surface temperature

Changes in water temperature can directly affect the growth rate and Food Conversion Ratio of the fish. Temperature also affects the oxygen levels and can cause harmful algae blooms, reduce water quality and an increase in occurrence of diseases and parasites which can than affect the fish or other culture species. A change in temperature can ultimately change the ranges of suitable species for a certain area but can also have positive impacts such as increased growth (mainly in tropical and sub-tropical regions) and a longer growing season. Primary productivity can also increase with increasing temperature, which may be beneficial for filter feeders such as mussels.

2) Risk of increased fragility of the aquaculture activity due to an increase of extreme weather.

Increased frequency and intensity of extreme weather events result in higher waves and storm surges and changes in salinity. These events result in loss of stock and damages to infrastructure and require adaptation in species selection, site selection and technologies.

Indeed, the objective of the risk assessment is to obtain final risk scores according to a gradient (very low to high) and to be able to compare the European islands with each other.

As mentioned in the part dedicated to the forest fire impact chain, the concept of Impact Chain (Schneiderbauer *et al.* 2013; Fritzsche *et al.* 2014) is also applied as a climate risk assessment method (with 7 steps for aquaculture, present risk and future risk are calculated

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separatly) for research of decision making. The goal of this method is to use collected data for certain indicators of the impact chains for different islands to assess the risks of each island's aquaculture sector to be affected by the hazard displayed in the impact chain. Therefore, data for all indicators were collected from all islands. After reviewing the data, selecting indicators and islands, the indicators were normalized, and different risk components were weighted. Using these values, the risks for present and future conditions under different Representative Concentration Pathway (RCP) scenarios were calculated for the different island and compared between each other. For the aquaculture impact chains, RCP 4.5 and 8.5 were compared since for the hazard models RCP 2.6 was not always available.

These steps will be described in detail in the following sections.

Step 1: Data collection by Island Focal Points

To be able to apply the GIZ risk assessment method, a solid data basis is crucial. Therefore, data was collected by the Island Focal Points (IFPs) of the SOCLIMPACT project. The questionnaire requested datasets for 16 indicators and topics with several subcategories on exposure and vulnerability. The IFPs reached out to local stakeholders and authorities to collect the requested data which was then resubmitted to the Sectoral Modelling Team (SMT) Aquaculture.

Step 2: Data review and island selection

Data were submitted by most of the islands to the SMT Aquaculture. Most datasets were incomplete with major data missing regarding important information for the successful operationalization of the impact chains. Therefore, and for the fact that some islands do currently not have any active marine aquaculture operations running, some islands were excluded from the operationalization. Out of the 12 islands assessed in the SOCLIMPACT project, six were included in the operationalization of the impact chains using the risk assessment method from GIZ: Corsica, Cyprus, Madeira, Malta, Sardinia and Sicily. The other six islands (Azores, Balearic Islands, Baltic Island, Canary Islands, Crete and French West Indies) do currently not have active marine cage aquaculture operations or show insufficient data availability. Data on hazards was provided by the models developed in work package 4. Eventually, Madeira was excluded for the impact chain on extreme weather events due to lack of reliable hazard data. A qualitative analysis will be provided in the result section.

Step 3: Review and selection of indicators

The data collection and review revealed that not all indicators of the impact chains could be used for the operationalization process. Therefore, these indicators were reviewed carefully and the ones which were not represented by sufficient data were excluded. The revised impact chain was developed depending on the indicators selected.

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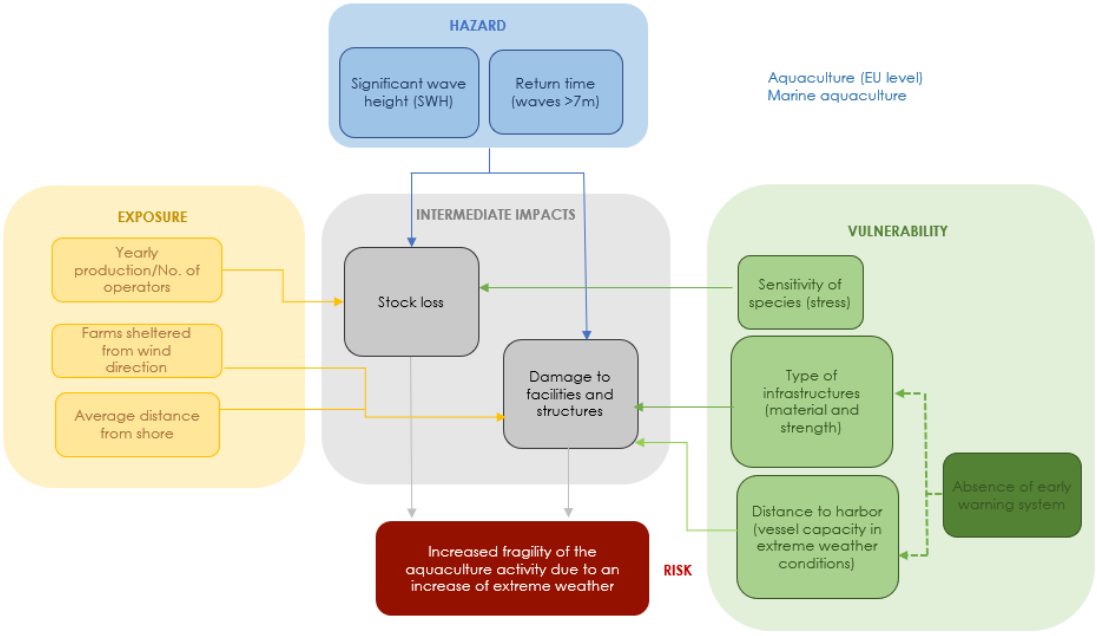

Figure 1: Impact chain on Increased fragility of the aquaculture activity due to an increase of extreme weather adjusted depending on data availability and used for the operationalisation.

Source: Soclimpact project deliverable 3.2

Impact chain: extreme weather events

Hazard

For the component hazard both indicators were used for the operationalisation. The wave amplitude was shown as significant wave height (SWH) in m and the return time number of years between extreme events quantified with a threshold of >7m. The data was derived from the climate models of Deliverable 4.4 at the exact locations where the fish farms are located and then averaged for all locations on one island. This allows a more accurate assessment than taking the average values for the entire island.

Exposure

Four indicators were selected to be operationalized. The number of aquaculture operators was provided by the IFPs and additional literature. There was no data available on the actual size of stock, therefore the yearly production of aquaculture products (fish and shellfish) in tons was used as a proxy indicator. The location of farms was rated by using two different proxy indicators: the location of the farms in relation to the prevailing wind direction and the average distance of the farms to shore. To be able to rate the location in relation to the wind direction, the values were estimated (with 0 being completely sheltered and 1 being exposed to wind and possible storms). After normalizing the distance from shore (measured by using GIS software and the exact coordinates of the fish farms), both values were averaged and represent the exposure of the location of farms.

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Sensitivity (vulnerability)

Two indicators were applied to calculate the score of factors of sensitivity. The sensitivity of species was estimated by reviewing literature and interviewing experts regarding the vulnerability of species to extreme weather events. After receiving these data, average values were calculated of all values for the present species on each island.

Table 1:Estimated vulnerability factors for the sensitivity of species to wave stress

1= very vulnerable to stress: 0=very resilient to stress.

Sensitivity of species for wave stress threshold				
Species	Sea bream	Sea bass	Tuna	Mussels & Clams
Estimated vulnerability factor	0.55	0.65	0.3	0.9

Source: Soclimpact project deliverable 4.5

The same approach was implemented to calculate the vulnerability of the infrastructure types used on each island based on the type of species farmed.

Table 2:Estimated vulnerability values for the vulnerability of infrastructure in case of an extreme weather event.

1= very vulnerable to stress: 0=very resilient to stress.

Vulnerability of aquaculture infrastructure in case of an extreme weather event			
Infrastructure for species	Sea bream & Sea bass	Tuna	Mussels & Clams
Estimated vulnerability factor	0.4	0.3	0.6

Source: Soclimpact project deliverable 4.5

Adaptive capacity (vulnerability)

The indicators distance to harbor and the presence of warning systems were used to describe the adaptive capacity. As there is a weather forecast available for all islands, the values for the presence of warning systems are all the same and represent low values. The distance to harbors was moved to the subcomponent adaptive capacity and measured using GIS software and the exact locations of the farms which were provided by the IFPs and literature data. It represents the average distance of all farms to their closest harbor for each island and is shown in meters. The indicator stocking density and engineering of structures were excluded from the operationalisation. For the stocking density there were no data available from all islands and in any case, it was estimated to be similar for all islands. The engineering of structures was already covered with the type of infrastructures in the sensitivity subcomponent.

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Impact chain: sea surface temperature

Hazard

Changes in surface water temperature was chosen to be the indicator representing the component hazard. The temperature data for this indicator was obtained from the location of each farm from the climate models of Deliverable 4.4 and averaged per island. To calculate the hazard for each island and each RCP, the species' temperature thresholds were taken into account. According to a literature review (see Annex) the temperature thresholds for farmed species is the following:

Table 3 :Temperature threshold per species.

Temperature thresholds for different species				
Species	Sea bream	Sea bass	Tuna	Mussels & Clams
Threshold (°C)	24	25	24	20.5

Source: Soclimpact project deliverable 4.5

It must be noted that the threshold for Tuna was set to 24°C since in the project only Tuna fattening is done (in Malta) and for adult fish the threshold is 24°C while in the review the whole life cycle as well as prey species was taken into account which is not relevant for this exercise. Based on these thresholds, the duration of the longest event per year (in days) was calculated for the temperatures 20 °C, 24 °C and 25 °C for RCP 4.5 and 8.5 from the models developed in WP4. After normalizing these values (which is described in detail in Step 4), the values for each temperature and therefore each species threshold were averaged using the sum product of the normalized values and the species' proportion on the total production of the island. The final values represent the score of the hazard. The indicator changes in seawater characteristics was not included in the operationalization as there is no additional data related to this indicator which is not covered by the surface water temperature indicator.

Exposure

Two indicators were used for the component exposure: the number of aquaculture operators and the yearly production (in tons) as a proxy indicator for the size of stock.

Sensitivity (vulnerability)

The subcomponent sensitivity includes two indicators which were combined to one indicator for the operationalization. The sensitivity of species directly correlates with suitable temperature for species and therefore it is summarized as temperature sensitivity of species. It was calculated by using temperature threshold values for each species

obtained from a literature review and expert opinion. These values were averaged depending on which species and in which quantities they are farmed on the islands.

Table 4 :Estimated vulnerability factors for the sensitivity of species to temperature stress

1= very vulnerable to stress: 0=very resilient to stress.

Sensitivity of species for temperature stress threshold				
Species	Sea bream	Sea bass	Tuna	Mussels & Clams
Estimated vulnerability factor	0.6	0.6	0.3	1

Source: Soclimpact project deliverable 4.5

Adaptive capacity (vulnerability)

Two out of four indicators from the impact chain were utilized for the operationalization. The monitoring early warning systems were included and show all the same values for all islands as there is a sea surface temperature forecast available for each island. The capacity to change species was included with all the islands displaying the same value as well. The risk value is high in this case, as it would be quite difficult to change species farmed on the islands in general as this would result in high economic expenditures. For the indicator of the impact chain know-how of recognizing and treating diseases/parasites there is no data available for any island. As this could vary a lot between the islands, the indicator was removed instead of making assumptions, to not negatively influence the risk values. A similar case arises from the indicator availability of alternative place for farming. There is no data available to make correct assumptions regarding the occurrence of alternative areas on the islands and therefore the indicator was not used for the operationalization.

Step 4: Normalization of indicator data for all islands

In order to come up with one final risk value per island and to be able to compare these values between islands, the indicator values were transferred into unit-less values on a common scale. The normalized values range between 0 and 1 with 0 being low risk and 1 being very high risk.
There are two different ways of normalizing the indicator values:

- Minimum/maximum normalization;
- Expert judgement.

Fraction of maximum normalization

This normalization method was used for indicators which were expressed by real data and not by expert judgement. The value for each island was calculated as a fraction of the maximum value in de data set. Meaning the island with the maximum value was given 1 and the rest as a fraction thereof.

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The following indicators were normalized using this method:

Extreme weather events:
- yearly production/ number of aquaculture operators
- average distance from shore (location of farms)
- average distance to harbour

Sea surface temperature: - yearly production/ number of aquaculture operators

Minimum/maximum normalization

This normalization method was used for indicators which were expressed by real data and not by expert judgement. The minimum and the maximum value of that indicator of all islands was calculated and the following formula was applied to normalize all indicator values to the scale between 0 and 1:

$$x_{normalized} = \frac{(x - x_{min})}{(x_{max} - x_{min})}$$

For both impact chains, the hazard values were normalised using the min and max method. However, in these cases the minimum and maximum values were not automatically the minimum and maximum values of the entire dataset but rather treated differently for every hazard indicator. This handling of the normalisation of the hazard indicators arose from the different nature of the indicator itself and the fact that data were available for different RCPs and periods of time. Therefore, the hazard indicators were normalised as following:

The sea surface temperature values were normalised separately for each temperature data set. This means that all values for all RCPs and time periods of one "longest event over a certain temperature" were taken into account when determining the minimum and maximum values. For Madeira, RCP 4.5 data was not available, therefore RCP 2.6 data was used and doubled.

Wave amplitude (significant wave height)

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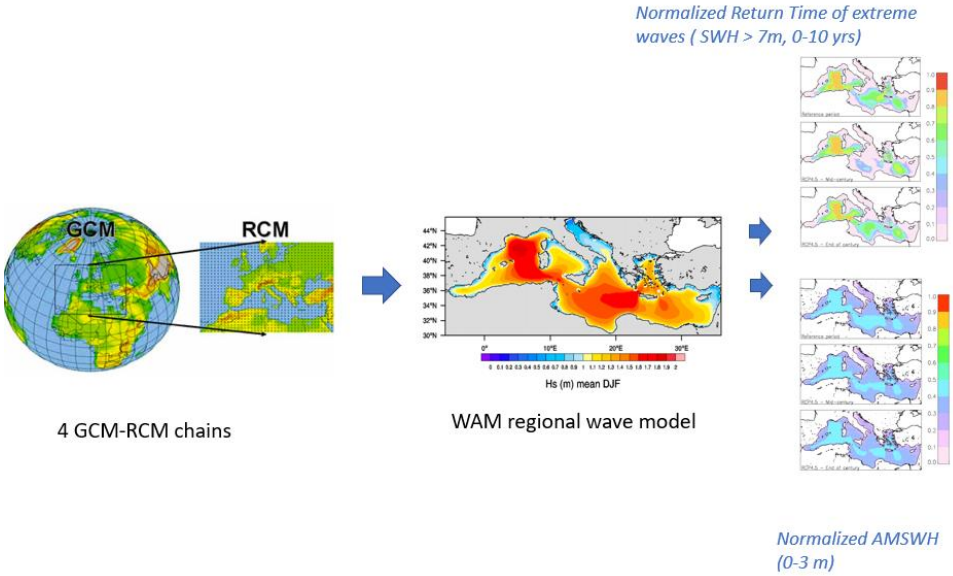

Figure 2: Modelling indicators for sea-state hazards, return time and significant wave height starting with 4 Global Circulation-Regional Circulation Model chains, which a fed into the WAM regional wave model. Results are then normalized.

Source: Soclimpact project deliverable 4.5

The return time was normalised as following; all values equal or greater that 10 are set to 0, all values between 0 and 10 are linearly mapped to the interval 1-0, so that 0 gives risk 1, 10 gives risk 0. It was assumed that a time period of 10 or more years allowed to repay investments is a reasonable threshold.

Since, as described in D4.4 of Soclimpact, that the probability of having at least one event exceeding the return level associated with a N-year return period during a N-year time window is anyway greater than that of its complement (no events exceeding the limit in the N-year time window), and that the return level cannot be considered a "no-risk" safety level in evaluating the survivability and sustainability of structures or plants.

Table 5: Probability of occurrence of at least one event exceeding the return level associated with a given return period (blue) in a given time window (green), according to the formula

*RL,T=1-(1-1/T)**L, where L=length of time window, T=Return Period.*

Return Period [years]	Probability of occurrence				
	1 years	2 years	5 years	10 years	20 years
5	20%	36%	67%	89%	99%
10	10%	19%	41%	65%	88%
20	5%	10%	23%	40%	64%

Source: Soclimpact project deliverable 4.5

Therefore, using a combination of the normalized values and the probability of occurrence, experts transformed these values into risk classes such all "low", "moderate", "medium", "high", "very high", or the like, on a qualitative basis.

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Expert judgement

For some indicators from both impact chains there was no data available which is the reason why expert judgement and estimations were applied. The following indicators were expressed using expert's estimations:

Extreme weather events:
- farm locations (in relation to main wind direction)
- sensitivity of species
- vulnerability of type of infrastructure
- presence of warning system

Sea surface temperature:
- estimated temperature sensitivity of species
- capacity to change species
- monitoring early warning systems

In all cases the normalization scale of 0 to 1 was applied with 0 being low risk and 1 being very high risk.

Step 5: Weighting of different risk components

In this step, the different risk components hazard, exposure and vulnerability (including the sub-components sensitivity and adaptive capacity) were rated. The total of the values sums up to 1. The weights were estimated by aquaculture experts and the basis of the estimations were subjective estimations, similar to the ones used in the AHP method. However, in this method the data availability was additionally taken into account. Components for which the available data was scarce, outdated or more unreliable the weights were set lower on purpose, while components with accurate datasets were given a higher weight as following:

Table 6: Components and their weights.

(Sub)Component	**Weight**	
	Sea surface temperature	*Extreme events*
Hazard	0.3	0.6 wave height 0.2 return time 0.8
Exposure	0.4	0.2
Vulnerability	0.3	0.2
Sensitivity	0.75	0.75
Adaptive Capacity	0.25	0.25

Source: Soclimpact project deliverable 4.5

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Step 6: Calculations of risk for present conditions

Before being able to calculate the risk values, the scores for each component/ subcomponent had to be calculated by taking the average of the corresponding indicators:

$$s_{comp} = \frac{(ind_1 + ind_2 + \cdots + ind_n)}{n}$$

s – *score*

comp – *component or subcomponent*

ind – *indicator*

n – *number of indicators*

The final risk value was calculated by summing up the scores of the components multiplied individually with the corresponding risk component weightings:

$$Risk = s_{haz} * w_{haz} + s_{exp} * w_{exp} + w_{vul} * (s_{sen} * w_{sen} + s_{ac} * w_{ac})$$

s – *score*
w – *weight*
haz – *hazard*
exp – *exposure*
vul – *vulnerability*
sen – *sensitivity*
ac – *adaptive capacity*

These risk values were calculated for each island individually and range between 0 and 1. After completing these calculations, it was possible to compare the islands between each other.

Step 7: Calculations of risk for future conditions (different RCPs)

To be able to project the risk values to future conditions, the operationalization was adjusted to the different Representative Concentration Pathways (RCPs). Therefore, the whole operationalization was duplicated and different values for the hazard indicators per island were inserted. These values were taken directly from the climate models provided in work package 4 for the different RCP scenarios (RCP 4.5 and 8.5). The resulting values can be compared between the islands as well as between the different RCP scenarios.

Results

Impact chain: extreme weather events

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Atlantic islands

Table 7: Risk results for impact chain Extreme weather events for the Atlantic Islands

	Hadley centre			ACCESS		
Risk	Historic	RCP 8.5 Mid century	RCP 8.5 End-century	Historic	RCP 8.5 Mid century	RCP 8.5 End-century
Azores	0.83	0.76	0.79	0.15	0.41	0.67
Madeira	0.20	0	0.01	0	0	0

Source: Soclimpact project deliverable 4.5

For the Atlantic islands, 2 models are available (Hadley Centre and ACCESS) for data on return time. The results of these models are highly variable. For the Azores even the change of the risk is different, where the Hadley riley model shows a decrease in risk while ACCESS shows a significant increase in risk. Therefore, no conclusion can be made. For Madeira, the risk in the future will be nihil. Not considering probability, it could be concluded that climate change has no or a positive effect on the occurrence on extreme events in Madeira. However, since this data is not accurate, more work needs to be done.