Horizon 2020 Societal challenge 5: Climate action, environment, resource efficiency and raw materials

BINGO

Bringing INnovation to onGOing water management – a better future under climate change

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Short Summary of results (<250 words)
Deliverable 4.6 – “*Indicators of scenarios of risk caused by extreme weather events at the six research sites*” is the last deliverable of workpackage 4. Estimated the risk, it establishes indicators of future changes appropriated for each research site. These changes refer to climate, hazard or vulnerabilities.

Evidence of accomplishment
Report

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ACRONYMS

ARBVS	Associação de Regantes e Beneficiários do vale do Sorraia (Association of Irrigators and Beneficiaries of Sorraia Valley)
BINGO	Bringing INnovation to onGOing water management
CC	Climate change
CSO	Combined Sewer Overflows
CY	Cyprus
D	Deliverable
DE	Germany
EDP	Eletricidade de Portugal (Electricity of Portugal)
EPAL	Empresa Portuguesa das Águas Livres – Grupo Águas de Portugal (EPAL – Public Water Supply Company to Lisbon and all the right margin of lower Tagus river)
EU	European Union
HQ	Return period for flood events
IPMA	Instituto Português do Mar e da Atmosfera (Portuguese Institute for Sea and Atmosphere)
LGVFX	Lezíria Grande de Vila Franca de Xira
MAP	Mean Annual Precipitation
NL	Netherlands
NO	Norway
PIP	Public Irrigation Perimeter
Prob	Probability
PT	Portugal
PWS	Public Water Supply
Q	Flow
RS	Research Site
SNIRH	Sistema Nacional de Informação de Recursos Hídricos
SP	Spain
T	return period
WP	Work package
Vol	Volume

1 INTRODUCTION

Workpackage 4 analysed the risk introduced by climate change scenarios at the six research sites. Workpackage 5 deals with measures to reduce some of these risks.

The purpose of this report is to establish indicators of risk caused by extreme weather events at the six research sites. They can be seen as warning and action indicators will be suggested to manage conflicts generated by socio economic activities facing extreme climatic events.

Indicators can be of different types: climatic change; hazard changes; any sort of vulnerabilities change, etc. These indicators, by presenting a certain deviation from a reference level, can trigger the implementation of a certain measure.

Indicators may also be a measure of the degree of implementation of an action concerning climate change (CC) adaptation.

Indicators link workpackage 4 with workpackage 5, where the risks are treated.

Chapter 2.1 list the indicators developed for the six researches sites.

Chapter 2.2 presents a brief justification or context for their selection.

2 INDICATORS

2.1. Indicators definition

The indicators selected for each research site are presented from Table 2.1 to Table 2.6. A brief description of each one is also provided.

Table 2.1: Indicators – Portugal (lower Tagus)

RS	#	Objective	INDICATOR	DESCRIPTION
PT	1	Climate change (Zêzere Basin)	Decadal Moving Average of " 30-years Mean Annual Precipitation (MAP)": i) Trend (either always increase or decrease) ii) Magnitude: $\triangle > 1.5\%$ *Zêzere Basin (C. Bode reservoir):* $\triangle$ MAP$_{(1981\text{-}2010)}$ - MAP$_{(1971\text{-}2000)}$$^{(a)}$ > 1.2 % $\triangle$ MAP$_{(1991\text{-}2021)}$ - MAP$_{(1981\text{-}2010)}$ > 1.2 % … (a) MAP$_{(1971\text{-}2000)}$: 848.5 mm (weighted value of 3 climatologic stations: Guarda; Castelo Branco and Coimbra) - IPMA official values	This indicator intends to detect changes in average annual precipitation along time, in the future, based on observed values. The changes in precipitation will have impact in the inter-annual storage regulation reservoirs. The 30-year Mean Annual Precipitation (MAP) is considered the relevant variable of analysis. The difference between successive decadal averages, either in trend (always positive or negative) and magnitude, is the indicator selected to detect the extent of CC in the future. IPMA (Institute for Sea and Atmosphere) provides the 30-yrs period's averages for the capitals of districts in Portugal. For each basin, 3 surrounding climatic stations were selected, to provide spatial representativeness.
PT	2	Climate change (Sorraia Basin)	Decadal Moving Average of " 30-years Mean Annual Precipitation (MAP)": i) Trend (either always increase or decrease) ii) Magnitude: $\triangle > 1.5\%$ *Sorraia Basin (Maranhão and Montargil reservoirs):* $\triangle$ MAP$_{(1981\text{-}2010)}$ - MAP$_{(1971\text{-}2000)}$$^{(b)}$ > 1.2 % $\triangle$ MAP$_{(1991\text{-}2021)}$ - MAP$_{(1981\text{-}2010)}$ > 1.2 % … (b) MAP$_{(1971\text{-}2000)}$: 730.9 mm (weighted value of 3 climatologic stations: Portalegre; Évora and Santarém) – IPMA official values	
PT	3	Hazard change (agriculture - Sorraia PIP)	Prob.(Vol.$_{\text{availability}}$ <0.75 x Vol.$_{\text{demanded}}$) > 5%	The real hazard relies in the incapacity to fulfil demand, rather than in average precipitation. This indicator allows understanding that action upon demand is also possible (and desirable).
PT	4	Hazard change (agriculture - Lezíria PIP)	Tagus river discharge at the SNIRH's Almourol station (monthly average of June) (Q) ≤ Q measured during the drought of 2012	Decrease in the Tagus river discharge increases the risk of unavailability of water for irrigation (salinity>1) during high Spring tides. During droughts, the negative impacts on the agriculture (e.g. loss of crops) are particularly relevant in the month of July, when the water scarcity starts and all the crops are in place.
PT	..	Hazard change (agriculture - Lezíria PIP)	Annual rate of sea level rise at the Cascais DGT's tide gauge (mm/year) compared with the current rate (4.1 mm/year)	The present rate of sea level rise at Cascais is about 4.1mm/year and the data suggest that it will keep on increasing. The rate of sea level rise at Cascais is an indicator of changes in inundation hazard in the LGVFX.

Table 2.2: Indicators – Cyprus (Peristerona Watershed)

RS	#	Objective	INDICATOR	DESCRIPTION
CY	1	Climate change	Reduction in mean annual precipitation (% or Δmm), relative to 1980-2010 reference (Camera et al., 2014)	The reduction of precipitation decreases streamflow, which recharges groundwater, which is the primary source for domestic water supply and irrigation
CY	2	Climate change	Increase in mean annual temperature (% or Δ^{o}C), relative to 1980-2010 reference	The increase in temperature results in an increase in evapotranspiration, which increases irrigation water demand, reduces the streamflow and thereby the groundwater recharge, which is the primary source for domestic water supply and irrigation
CY	3	Climate change	Change in hydrologic drought: change in 2-year Standardized Precipitation Index (SPI) (relative to 1980-2010 reference)	Reduction or lack of streamflow and groundwater recharge in the downstream area.
CY	4	Climate change	Change in agricultural drought: change in 1-month Standardized Precipitation Index (SPI) (relative to 1980-2010 reference)	Insufficient soil moisture results in reductions and failures of rainfed crop production (barley) and increases the costs of livestock feed.
CY	5	Climate change	Change in ecohydrological drought: change in 1-year Standardized Precipitation Index (SPI) (relative to 1980-2010 reference)	Insufficient recharge of the fractured bedrock affects the pine forests on the northern Troodos hillslopes and makes the trees susceptible to pests, diseases and dieback
CY	6	Vulnerability change	Change in shares of domestic water supply sources (groundwater & desalination) (%), relative to 2018 (100% groundwater)	Change in the share of domestic water supply sources towards desalination increases water prices and the cost of non-revenue water
CY	7	Vulnerability change	Change in irrigation water prices (%), relative to 2018 prices	Irrigation water prices affect irrigation water demand and irrigated area
CY	8	Vulnerability change	Population change (%), relative to Census 2011	Population change affects domestic water demand

Table 2.3: Indicators – Netherlands (Veluwe)

RS	#	Objective*	INDICATOR	Description
NL	1	Climate Change	Level of winter precipitation (% or mm) compared to 1984-2014 average. An increase of 18% is expected, anything below that indicates a risk scenario.	Winter precipitation is expected to increase with 18% until 2050. A lower increase of decrease of the winter precipitation means less water infiltrates into the Veluwe groundwater system.
NL	2	Climate Change	Average temperature (T) compared to the 1984-2014 average as reported by KNMI (De Bilt). Any increase indicates a risk scenaro	Increase in average temperature may lead to increased water demand and an extended growth season, resulting in more evapotranspiration, a higher water demand by nature and less infiltration into the Veluwe groundwater system.
NL	3	Vulnerability Change	Water demand compared to the 2004-2014 average. Any increase above 30% in 2050 (Economy First Scenario) indicates a risk scenario.	An increase in water demand due to population growth, industrial growth, changing behaviour or increased temperatures will increase the abstractions from the Veluwe groundwater system.
NL	4	Vulnerability Change	Decrease in base flow of brooks and streams compared to the 1984-2014 average. Any decrease indicates a risk scenario.	The base flow of the brooks and streams are an indicator of the groundwater levels of the Veluwe system. A decrease in base flow may indicate a decrease in groundwater levels.

Table 2.4: Indicators – Germany (Wupper)

RS	#	Objective*	INDICATOR	Description
DE1 (not enough water)	1	Climate change	Decrease of precipitation in the Wupper basin during spring time (precipitation in spring is important for the filling of reservoirs). The past long-time (1900-2011) average precipitation in April in the Wupper basin is 87mm. The linear trend of April precipitation shows a decrease of 25 mm in the last decades.[1] **Indicator:** Increasing negative deviation of decadal moving average from long-time average April precipitation in 5 consecutive years.	Precipitation in spring time is important for filling the reservoirs. Although the mean annual precipitation remained relatively constant, the rainy seasons shifted within a year.[1] Therefore the increase of dry periods in spring time can act as indicator for negative climate change effects. [1] aus der Beek, T., van Alphen, H.-J., Alves, E.; Bruggemann, A.; Camera, C.; Fohrmann, R.; Fortunato, A.; Freire, P.; Iacovides, A.; Iacovides, I.; Kristvik, E.; Kübeck, C.; Lorza, P.; Muthanna, T.; Novo, E.; Rocha, F.; Rodrigues, M.; Rodrigues, R.; Russo, B.; Sánchez, P.; Scheibel, M.; Spek, T.; Wittel, F.; Zoumides, C.: D3.1 – Characterization of the catchments and the water systems (2016). BINGO.
	2	Vulnerability change	Increase of raw water use compared to past raw water usages (values from the years 2000, 2005, 2010, 2015). Raw water usages in past years[2]: 2000: 55.38 Mm^3 2005: 49.83 Mm^3 -10.02 % 2010: 49.40 Mm^3 -0.86 % 2015: 48.33 Mm^3 -2.17 % **Indicator:** FutureWaterUse / PastWaterUse > 1.03 (3% increase) (Increase of water use considered as significant if >3%) Or FutureWaterUse / PastWaterUse > 1 in three consecutive years (Increases <3% considered as significant if occurring in three consecutive years)	From the year 2000 to the year 2005 the raw water consumption was reduced by approx. 10 %, inter alia due to water saving efforts of the population and an increasing awareness of the population with regard to water resources. After that, the yearly raw water consumption remained relatively constant at around 49 Mio. m^3. This value might act as reference value for future raw water consumptions. [2] van Alphen, H.-J,Iacovides, A., Mouskoundis, M., Iacovides, I.; Russo, B.; Sánchez, P.; Carretero, J.-A. M.; Gragne, A. S.; Kristvik, E.; Lorza, P.; Scheibel, M.; Rodrigues, R.; Henriques, M. J.; Alves, E.; Rodrigues, M.; Spek, T.; aus der Beek, T.: D3.2 - Future Land and Water Use Scenarios (2018). BINGO.

DE2 (Too much water)	3	Climate change	Increase of probabilities of flood events. At the moment an HQ100 event at the Mirke Creek is characterized e.g. by a flow rate of 25 m^3/s at element 1000 of the computational domain of the Mirke Creek.[3] **Indicator:** Increase of probability of an actual HQ100 event from actually 0.01 to a probability > 0. 011 (an event that is actually characterized as HQ100 is expected to be at least an HQ90 in the future).	The frequency of heavy rainfall events affecting the water level in the Mirke Creek might increase in the future. Thus the change of frequency of a specific flood event to higher frequencies might be used as indicator for climate change related risks. [3] aus der Beek, T.; Alves, E.; Becker, R.; Bruggemann, A.; Fortunato, A.B.; Freire, P.; Gragne, A.; van Huijgevoort, M.H.J.; Iacovides, A.; Iacovides, I.; Kristvik, E.; Locatelli, L.; Lorza, P.; Mouskoundis, M.; Muthanna, T.; Nottebohm, M.; Novo, E.; Oliveira, M.; Russo, B.; Scheibel, M.; Sunyer, D.; Teneketzi, E.; Vayanou, P.; Viseu, T.; Voortman, B.R.; Witte, J.P.M.: D3.4 – Model results for water and land use scenarios completed and analysed (2018). BINGO.

Table 2.5: Indicators – Norway (Bergen)

RS	#	Objective*	INDICATOR	Description
NO	1	Climate change	Increased frequency or intensity of extreme events. For a specific design duration (catchment concentration time [min]) and return period T [years], the precipitation intensity can be retrieved and the indicator given as the % increase between the base period and present (time of estimation): %-increase $R_{present}(T, D) – R_{base}(T, D) > 10\ \%$ present = estimate based on data from observation start to present date base = estimate based on data from observation start to baseline year 2018	Bergen is expected to experience increased precipitation amounts and more high-intensity rainfall events. Such events cause overloading of combined sewer systems and pollution of receiving water bodies
NO	2	Vulnerability change	More leisure activities close to receiving water bodies, indicated by population (POP [nr.of]) growth %-increase $POP_{Post\text{-}development} - POP_{Pre\text{-}development} > 5\%$	More activities around receiving water bodies due to city development, population growth in developed area and increased / improved public spaces makes the public more exposed.
NO	3	Evolution of soil occupation	Increase of impermeable surfaces (IS [m2]) in the catchment. %-increase $IS_{Post\text{-}development} - IS_{Pre\text{-}development} > 1\%$	City densification often lead to more paved and impermeable surfaces which prevent natural infiltration to soil and lead to quicker runoff and increased risk of CSO. In addition, increased area of paved surfaces reduces available space that potentially could host surface-based blue-green stormwater measures preferred for climate adaptation.

Table 2.6: Indicators – Spain (Badalona)

RS	#	Objective*	INDICATOR	Description
SP	1	Climate change	Increase of future (2050-2010) rainfall intensity. The current 2 year return period event will increase by 15 % The current 10 year return period event will increase by 7 % The current 100 year return period event will increase by 2 % The current 500 year return period event will increase by 1 %	The increase of rainfall intensity increases the extent of the urban area with high flood hazard and risk.
SP	2	Climate change	Variations of future (2015-2024) vs past (2005-2014) seasonal precipitation volume and number of rainfall events. The seasonal number of CSO events is estimated to increase by 13%, whereas the seasonal accumulated CSO volume is estimated to decrease by 3%. The seasonal duration of unacceptable bathing wàter quality for the future period (2015-2024) is similar to the present period (2005-2024). Also, the future duration of unacceptable bathing wàter quality after CSOs is similar to the present duration.	Variations of seasonal precipitations affect the total Combined Sewer Overflow (CSOs) volume that is released to the receiving water body. Also, the seasonal number of rainfall events affects the number of CSOs. These changes affect also the duration of insufficient water bathing water quality after CSOs.
SP	3	Vulnerability change	Changes in future land use	No changes applied. Badalona is a consolidated city and only minor changes of land use are expected in the future.
SP	4	Vulnerability change	Changes in future traffic and pedestrian fluxes	No changes applied. No significant changes of pedestrian and vehicles are expected and therefore the exposure is considered unchanged.
SP	5	Vulnerability change	Changes in future exposure of bathing people	No changes applied. The number of tourists in the future is not forecasted to change.

2.2. Justification of indicators selection

2.2.1 Portugal (lower Tagus basin)

The major climatic hazard source in the Portuguese Tagus research site is the occurrence of extreme dry long periods, leading to potential water resources deficit, a hazard with impact on agriculture and dependent activities (agroindustry) and on public water supply (service provided by EPAL), sectors competing for the same water resources. Salt water intrusion in Tagus River is also a possible consequence of droughts.

Storm surges can also cause inundations in agricultural lands.

Hazard: Water resources deficit

Public water supply – Castelo do Bode

The main water source for public water supply is the multipurpose reservoir of Castelo do Bode, located in Zêzere river, a tributary of Tagus basin. It has plurennial regulation capacity. This reservoir is operated by one energy production company (EDP – Electricity of Portugal). Due a close cooperation between EDP and EPAL during past droughts the water storage in Castelo do Bode was managed in such a way that, together with other water sources, EPAL did not restrain significantly water supply (see D4.1 for details).

Indicator #1: A climatic indicator, based on 30-years Mean Annual Precipitation (MAP), was chosen to monitor climate change tendency in the region along time. In order to cover topographic variation, with impact in precipitation annual amounts, 3 surrounding district capitals were selected and averaged to provide the reference departure value of future comparisons. Table 2.1 lists the indicators selected and provides a short description or each one.

Agriculture – Sorraia PIP

Sorraia public irrigation perimeter has two reservoirs (Maranhão and Montargil), with at least one year regulating capacity (see D4.1 for details). The main use is for agriculture and the reservoirs are operated by the Sorraia Irrigator’s Association (ARBVS). Since 1992, the water stored in these reservoirs has been able to support agricultural campaigns. No water partitioning occurred since then. Nevertheless, for several times in dry years the perspective of a deficit was feared, the last time occurred in 2018. Figure 2.1 shows how reduced was water storage in Maranhão in February and how the situation was reversed in march due to intensive precipitation (https://snirh.apambiente.pt/index.php?idRef=MTE3Nw==&simbolo_redehidro=19J/01A).

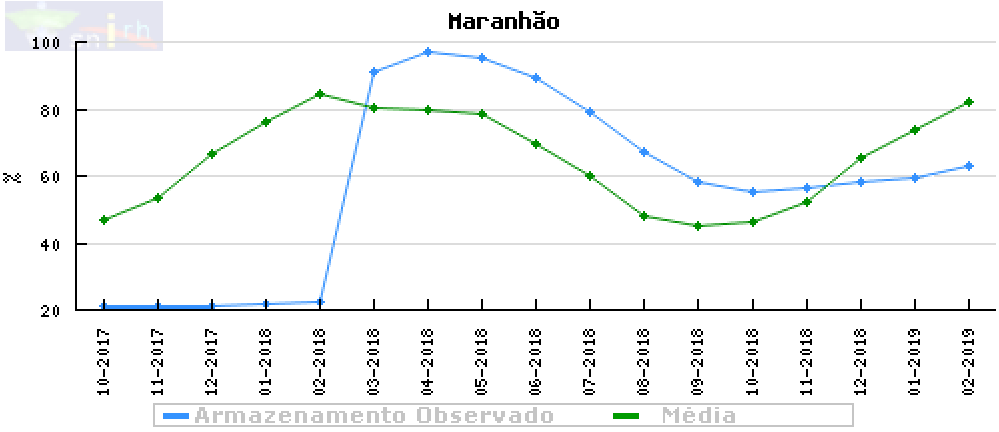

Figure 2.1: Evolution of water storage in Maranhão reservoir in the hydrological years of 2017/18 e 2018/19. Green line – average; Blue line – observation. Source: SNIRH

Indicator #2: A climatic indicator, based on 30-years Mean Annual Precipitation (MAP), was chosen to monitor climate change tendency in the region along time. The real hazard relies in the incapacity to fulfil demand (water resources deficit), rather than in average precipitation.

Indicator #3: As the reservoirs are managed by the Irrigator's Association, a hazard indicator was also selected (Figure 2.1).This indicator allows understanding that action upon demand is also possible (and desirable).

Agriculture – Lezíria Grande de Vila Franca de Xira Public Irrigation Perimeter (Lezíria PIP)

Indicator #4: The main water intake in the Lezíria Grande de Vila Franca de Xira Public Irrigation Perimeter (Lezíria PIP) is located close to the limit of the salinity intrusion in the Tagus estuary. The water abstraction is limited by the salinity, hence by the river flow and the amplitude and phase of the tide. The saltwater propagation in the Tagus estuary is mainly driven by the combined effect of tides and freshwater discharge (Rodrigues and Fortunato, 2017). During low river discharges, saltwater propagates further upstream (see D3.4 for details).

The most recent droughts, in 2005 and 2012, affected the agricultural activities in the Lezíria PIP and emergency measures were undertaken to minimize the negative impacts of water scarcity and, in particular, the loss of crops. Here we consider the year of 2012 as a reference, since during the drought of 2012 (which was less severe than the drought of 2005) salinity already reached concentrations at the water intake that were inadequate for irrigation.

Indicator #5: We suggest using the river flow of June in Almourol as an indicator of possible water scarcity in July based on the positive correlation between both monthly means (Pearson correlation coefficient = 0.55). The mean monthly river flow of June/2012 was approximately 65 m^3/s based on the data available on SNIRH (http://shirh.pt).

Hazard: Inundation

Agriculture – Lezíria Grande de Vila Franca de Xira Public Irrigation Perimeter (Lezíria PIP)

The Lezíria Grande de Vila Franca de Xira is surrounded by protective dikes. These dikes can be overflown, causing inundations, under two sets of circumstances: high river flow, and a combination of high spring tides and storm surges. Here we focus on the second type of circumstances.

The sea level is due to a combination of several factors: the mean sea level, the tide, the storm surge, and the wave setup. Both the storm surge and the wave setup are due to atmospheric effects. While storminess is increasing in some areas of the world due to climate change, several authors have shown that this is not the case in the Portuguese coast. Similarly, small changes in tidal elevations have been shown to occur as a result of sea level rise, but these changes are negligible along the Portuguese coast. Hence, the major driver of sea level changes in the Tagus estuary is the sea level rise.

Sea levels have been measured at Cascais for over a century. Analyses of these data have shown that, like along most of the world’s coastlines, sea levels are rising at an accelerated pace. Since 2010, the rate of sea level rise is about 4.1 mm/year at Cascais. This rate represents a significant increase compared to 2.1 mm/year between 1990 and 2005, and the data suggest that this rate will keep on increasing. Hence, we suggest using the rate of sea level rise at Cascais as an indicator of changes in inundation hazard in the upper Tagus estuary.

2.2.2 Cyprus (Peristerona Watershed)

The risk management process in Peristerona Watershed focus on the two main water uses in the region, namely domestic water supply and agriculture. The main hazards for both the domestic water supply and the agricultural sector in Peristerona Watershed are the reduction in streamflow and groundwater recharge, which are both triggered by the reduction and increased variability of precipitation. These two factors directly affect irrigation water demand and the streamflow from the upstream areas. The reduction in streamflow reduces the groundwater recharge in the downstream areas.

Indicator #1 *Reduction in mean annual precipitation*: The reduction of precipitation decreases streamflow, which recharges groundwater, which is the primary source for domestic water supply and irrigation. The reference is set by the 1980-2010 average (Camera et al., 2014)

Indicator #2 *Increase in temperature*: The increase in temperature results in an increase in evapotranspiration, which increases irrigation water demand, reduces the streamflow and thereby the groundwater recharge, which is the primary source for domestic water supply and irrigation

Indicator #3 *Change in hydrologic drought*: Reduction or lack of streamflow and groundwater recharge in the downstream area.

Indicator #4 *Change in agricultural drought*: Insufficient soil moisture results in reductions and failures of rainfed crop production (barley) and increases the costs of livestock feed.

Indicator #5 *Change in ecohydrological drought*: Insufficient recharge of the fractured bedrock affects the pine forests on the northern Troodos hillslopes and makes the trees susceptible to pests, diseases and dieback

Indicator #6 *Change in shares of domestic water supply sources*: Change in the share of domestic water supply sources towards desalination increases water prices and the cost of non-revenue water

Indicator #7 *Change in irrigation water prices*: Irrigation water prices affect irrigation water demand and irrigated area

Indicator #8 *Population change*: Population change affects domestic water demand.

2.2.3 Netherlands (Veluwe)

The Veluwe case study focuses on the water balance at the Veluwe, with the most important risks being long term drought (because of consecutive dry years). The Veluwe groundwater system is a primary source for drinking water and an important source for brooks and streams surrounding the Veluwe.

Indicator #1 Winter precipitation: Winter precipitation is essential for the recharge of the Veluwe groundwater system. This makes it an key indicator of the overall water balance at the Veluwe and a change in this indicator may trigger a drought scenario. Winter precipitation is expected to increase with 18% until 2050. A lower increase of decrease of the winter precipitation means less water infiltrates into the Veluwe groundwater system.

Indicator #2: Increase in average temperature may lead to increased water demand and an extended growth season, resulting in more evapotranspiration, a higher water demand by nature and less infiltration into the Veluwe groundwater system. So, if average temperature increases beyond current levels, drought conditions may exacerbate.

Indicator #3: An increase in water demand due to population growth, industrial growth, changing behaviour or increased temperatures will increase the abstractions from the Veluwe groundwater system. This can have a direct effect on the availability of water for other purposes. Also, the abstractions may exceed the current levels set by the regional government.

Indicator #4: The base flow of the brooks and streams are an indicator of the groundwater levels of the Veluwe system. A decrease in base flow may indicate a decrease in groundwater levels. This indicator is not an early warning, but more a late warning of low groundwater conditions at the Veluwe.

2.2.4 Germany (Wupperband)

Case Study DE1 - Indicator 1:

The focus of case study DE1 (Not enough water) lies on the provision of a sufficient amount of water from the Große Dhünn reservoir for contractual partners, public raw water supply and a mandatory downstream ecological flow. Furthermore, the restriction to ensure a minimum water level of 35 Mio. m^3 in the reservoir must be considered (source: D4.4). Two main factors are relevant for the risk assessment, namely the water inflow to the reservoir and the water demand for the above named purposes.

Indicator 1 focuses on the water inflow which is highly dependent on climate change. A reduction of precipitation is directly linked to a reduction of inflow to the Große Dhünn reservoir, thus this indicator may be used to estimate changes in water availability.

Case Study DE1 - Indicator 2:

As already described, the water balance in the Große Dhünn reservoir is dependent on the water inflow and the water demand. Indicator 2 of this case study enables to estimate the influence of changing water uses. The higher the increase of water demand and thus the increase of water withdrawal from the reservoir, the higher will be the risk of water deficits.

Case Study DE2- Indicator 1:

In case study DE2 (Too much water) the focus lies on the risk assessment of pluvial floodings at the Mirke Creek. Different hotspots are investigated that have differing drainage capacities. In case of high rainfall intensities, the drainage capacity at the hotspots is exceeded leading to urban floods. It is expected that the annualities of rainfall intensities causing pluvial flooding will increase in the future due to climate change, thus also the damages caused by urban floods are expected to increase. Therefore the change of annualities of different rainfall events may be used to estimate the change of probabilities of different hazardous flood events.

Case Study DE2- Indicator 2:

One of the consequences dimensions of flood risk assessment in the DE2 case study is the amount of yearly monetary damages. Due to the expected increased frequencies of high rainfall intensities and thus high flood water levels, also the sum of annual monetary damages caused by floods is expected to increase. Thus the expected annual damage is a suitable indicator to estimate the consequences dimension of risks connected to pluvial flooding.

2.2.5 Norway (Bergen)

The stormwater management at the Bergen research site, Damsgård, is based on a combined sewer system, with several CSOs discharging to the subjacent fjord Puddefjorden. The same area has previously been dominated by industrial activities along the water front, but is undergoing a large scale transformation where the industrial areas are being rezoned to urban residential purposes. Due to this, the risk management objective of BINGO has been to prepare the urban drainage system to avoid CSO during extreme precipitation conditions. CSOs occur during precipitation events with high intensity such that the capacity of the sewers is reached. The system is in such case unloaded by releasing combined sewage directly to the fjord. This causes negative impacts on the water quality.

Three risk indicators have been defined. For the hazard, increased precipitation intensity (Indicator 1) and increased area of impermeable surfaces (Indicator 3) within the catchment are chosen because they both, alone or in combination, will lead to quicker runoff and thus increased probability of the system being overloaded.

On the vulnerability side, public exposure is of main concern. Different leisure activities in and around the fjord, such as bathing, fishing, kayaking, etc. makes people more exposed to the risk and are therefore factored in. Population growth (Indicator 2) in the Damsgård area is chosen as the indicator. The reasoning for this is that leisure activities are difficult to monitor and that the increased population, in combination with the urban developments along the fjord (construction of bathing spots, promenades, etc.) also will increase the activity level, and thus, public exposure.

2.2.6 Spain (Badalona)

The research site of Badalona aims at developing a risk assessment for urban flooding and Combined Sewer Overflows (CSO).

The flood risk has been assessed for two different targets: for people safety in terms of pedestrians and vehicles stability and for the economic sector in terms of direct damages on properties (buildings, infrastructures, public spaces, etc.) and indirect damages (businesses interruption). Flood risk assessment has been carried out for current and future (Business as usual) scenarios according to the CORDEX projections (RCP 2.6, 4.5 and 8.5 scenarios) considering different return periods (from 2 up to 500 years). The acceptable level of risk regarding pluvial floods has been agreed with the Badalona City Council (risk owner of the research site) and other internal and external stakeholders and according to the lessons learnt by the Civil Protection department. Risk maps have been elaborated by crossing hazard and vulnerability maps. Flood hazard and vulnerability have been also assessed through methodologies agreed with the other partners. Because RCP 2.6 is considered an unrealistic scenario and RCP 4.5 gave future decreases of rainfall intensities, the RCP 8.5 scenario was used in the analysis.

The Indicator #1 estimates the future increase of rainfall intensity. The increase of actual design storms due to climate change was estimated based on RCP 8.5 results (2050-2100). The actual 2 year return period design storm is estimated to increase by

15%. Also, the 10, 100 and 500 year return period design storms will increase by 7, 2 and 1% respectively. The increase of rainfall intensity increases the extent of the urban area with high flood hazard and risk.

The CSO risk is quantified for people safety (people bathing in contaminated sea water after CSOs) and will also be assessed in terms of loss of public trust and, for the economic sector, in terms of indirect impacts on tourism, fishing and leisure activities.

The Indicator #2 shows that the seasonal number of CSO events is estimated to increase by 13%, whereas the seasonal accumulated CSO volume is estimated to decrease by 3%. This is due to changes in rainfall volumes, intensities and distribution in the future period (2015-2024) compared to the part period (2005-2015). The future risk is estimated to be similar to the present risk. In fact, the seasonal duration of unacceptable bathing water quality for the future period (2015-2024) is similar to the present period (2005-2024). Also, the future change in the duration of unacceptable bathing water quality after rainfall events is not significant.

The vulnerability indicators (#3, #4 and #5) concern with changes in future vulnerabilities, particularly, future land use, traffic and pedestrian fluxes and exposure of bathing people. These indicators are not expected to change in the period 2015-2024 compared to the past 2005-2014.

3 Final remarks

All the indicators selected are focused either on climate change (hazard source) or hazard change or any sort of vulnerability change. These are risk factors; a change in any of them will have an impact on the risk level.

The monitoring of these indicators will indicate the extent of changes and trigger the implementation of measures.

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