Deliverable C.3: Report on water related impact and adaptation assessment

LIFE URBANPROOF

CLIMATE PROOFING URBAN MUNICIPALITIES

Acknowledgements

This report was produced under co-finance of the EC LIFE programme for the Environment and Climate Action, in the framework of Action C.3 “Water-related vulnerability and adaptation assessment” of the project LIFE UrbanProof (LIFE15 CCA/CY/000086) “Climate Proofing Urban Municipalities”.

The project is being implemented by the following partners:

Coordinator Beneficiary	
DEPARTMENT OF ENVIRONMENT	Department of Environment, Ministry of Agriculture, Rural Development and Environment *(Cyprus)*
Associated beneficiaries	
	National Technical University of Athens *(Greece)*
	National Observatory of Athens *(Greece)*
IUAV Università Iuav di Venezia	University of Venezia *(Italy)*
COMUNE DI REGGIO NELL'EMILIA	Municipality of Reggio Emilia *(Italy)*
STROVOLOS MUNICIPALITY	Municipality of Strovolos *(Cyprus)*
LAKATAMIA MUNICIPALITY	Municipality of Lakatamia *(Cyprus)*
Municipality of Peristeri	Municipality of Peristeri *(Greece)*

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Executive summary

In the current report, a climate change impact and adaptation assessment is conducted for the municipalities of Peristeri (Attica region, Greece), Reggio Emilia (Emilia-Romagna region, Italy) as well as for the neighboring municipalities of Strovolos and Lakatamia (Lefkosia district, Cyprus), in the frame of the LIFE UrbanProof project. The scope of the assessment refers to the impacts of water availability, droughts and floods, which are examined with respect to the future periods of 2031-2060 and 2071-2100. The data on climate change projections used in the assessment are based on the emission scenarios RCP4.5 and RCP8.5. A methodology was developed for the assessment of water related climate change impacts on the urban environment, according to which the impacts are conceived as a function of the climate change hazards and the vulnerability of the exposed population, with the latter depending on the exposure and sensitivity of systems. A composite social vulnerability index was built combining those social indicators considered more relevant for the assessment of the water and flood impact assessments. These indicators refer to population age, chronic illnesses, poverty rate, educational level and hospital beds per inhabitant.

For the impact assessment of water availability under climate change a number of commonly accepted indicators was used, such as the Water Exploitation Index (WEI) and the Standardized Precipitation Evapotranspiration Index (SPEI). Water availability in the frame of the current assessment is assessed at the wider river basin management level where the main domestic water supply sources of the project municipalities are located. The results for the case of the reservoirs supplying the municipality of Peristeri, indicate a reduction of 20-24% the period 2031-2060 in water inflow according to RCP8.5 and a reduction of 46-49% for the period 2071-2100, while according to RCP4.5 the maximum expected reduction is 11% for the period 2071-2100. For the case of the reservoirs supplying the Cypriot municipalities, significant reductions are expected for both climate change scenarios. In particular, according to RCP4.5 a reduction of 24-48% and 35-59% is expected during the periods 2031-2060 and 2071-2100, respectively. Based on RCP8.5 the reduction is higher for the period 2071-2100 ranging from 63 to 76%. For the case of the aquifer supplying Reggio Emilia municipality, no significant changes in groundwater recharge are expected for any of the climate change scenarios and periods examined.

Following, the WEI was calculated based on the available data for annual inflow, abstractions and storage. Future abstractions were calculated on an annual basis based on the average water abstractions per capita for the baseline period which is multiplied with the projected population for a given year in the future. In that sense, water demand patterns are considered constant for the future periods while total abstractions change proportionally to population changes. The results for the case of Lefkosia district show that the WEI for the baseline period is already high (91-94%) for all relevant reservoirs, meaning that available water resources barely satisfy water demand. As water storage is relatively low in all relevant reservoirs, the foreseen decrease in annual inflow due to climate change and the increase in withdrawals due to

population increase will result in the depletion of water stored in the reservoirs and to inability to satisfy a significant part of water demand. For the case of Attica region the WEI for the baseline period is also high (94-96%) for both reservoirs, while according to RCP4.5 the WEI for both future periods will decrease to 36-72%. According to RCP8.5, the WEI for the case of Evinos reservoir will increase up to 118% while for the case of Mornos reservoir it will slightly decrease. For the case of the Reggio Emilia province and the Enza aquifer, the WEI for the baseline period is 60%, while for the period 2031-2060 it will increase up to 109% and for the 2071-2100 period it will further increase up to 164%, while the increase is mainly attributed to the high rate of abstractions and not to climate change impacts.

With respect to droughts, one may observe that overall drought intensity has an increasing trend with the exception of Cyprus and Greece during the period 2071-2100 where drought intensity slightly decreases compared to the period 2031-2060. Overall drought frequency has an increasing trend in all examined water bodies throughout the time periods. The change of drought risk in the future periods compared to the baseline period, is very high for the case of the South Conveyor system of Cyprus where drought risk is almost double for both future periods (92-95% increase). Furthermore, a significant increase is also observed during the period 2071-2100 for the case of Enza aquifer in Italy (57%) while lower increases are also observed for all other cases.

Overall, the highest impact on water resources is expected for the case of Cypriot municipalities as they gather the highest score in all future periods and scenarios. The climate change impact on water resources for Peristeri municipality is expected to be "moderate to high" in all examined cases apart from the period 2031-2060 and RCP8.5 where the impact is expected to be "moderate". The impact for Reggio Emilia municipality is expected to be "moderate to high" in all cases apart from the period 2071-2100 and RCP4.5 where the impact is estimated to be "high".

With respect to the flood impact assessment, flood hazard maps produced by the competent national authorities in compliance with the Floods Directive 2007/60/EC were used for identifying the location and extent of the area potentially affected by flooding (flood hazard zone) in each municipality. The hazard indicator is enhanced with an extra weight where low-lying areas (inclination: $<1^{o}$) are located next to rivers. Exposure to floods takes into account both population and critical infrastructure within the flood hazard zone. The exposure is also estimated with respect to the critical infrastructure exposed to floods, such as hospitals, schools, commercial and industrial areas, public facilities, cultural units and transport infrastructure. The effect of green space in reducing the flood impact is also estimated, with the quantification of the adaptation effect by means of runoff coefficients. The assessment results show that the municipality of Peristeri is expected to face the most significant flood impacts with the flood zone covering 29% of its total area, and an overall impact score of the flood zone area classified as "high", which is translated to a "medium to high" overall impact score for the municipality. Next are the municipalities of Strovolos and Lakatamia with a “medium” overall flood impact score for the municipality and the municipality of Reggio Emilia with a “low to medium” overall flood impact score for the municipality.

For the adaptation assessment, a review of the available adaptation measures for addressing water availability and flood climate change impacts took place. Following, a questionnaire was developed for the evaluation of the adaptation measures based on a set of criteria (Multi-Criteria Analysis, MCA). Potential adaptation measures evaluation was based on four criteria related to efficiency, environmental friendliness, economic viability and job growth. The measures were evaluated against these criteria by a number of experts & stakeholders (national, regional, local authorities; neighbouring municipalities and Unions; NGOs & CSOs; companies; academic bodies & research institutes) from Italy, Greece and Cyprus. The total score attained was used for the prioritization of the adaptation measures in their inclusion to the adaptation strategies of the project municipalities. Furthermore, the effect of the adaptation measures in moderating the impacts of water availability and floods (impact after adaptation) is assessed.

1. Introduction

In the current report, a climate change impact and adaptation assessment is conducted for the municipalities of Peristeri (Attica region, Greece), Reggio Emilia (Emilia-Romagna region, Italy) as well as for the neighboring municipalities of Strovolos and Lakatamia (Lefkosia district, Cyprus). The scope of the assessment refers to the impacts of water availability, droughts and floods, which are examined with respect to the future periods of 2031-2060 and 2071-2100. The data on climate change projections used in the assessment are based on the emission scenarios RCP4.5 and RCP8.5. The adaptation assessment includes the multi-criteria evaluation of selected adaptation measures as well as the assessment of the effect from the implementation of the adaptation measures. The impact and adaptation assessment is carried out in the frame of Action C.3 of the project LIFE UrbanProof "Climate Proofing Urban Municipalities" while the assessment results will be used for the development of the adaptation strategies of the municipalities in the frame of Action C.7 of the project.

In the second chapter of the report, the overall methodology for the impact and adaptation assessment used is laid down, including the definitions of the frequently used terms, the functional relationship of the relevant indicators and the methodological steps followed. In the third chapter of the report, the individual social vulnerability indicators comprising the social vulnerability index are presented as well as the methodology for the classification of their values. In the fourth chapter of the report the assessment for the water availability and drought impacts takes place. At first the relevant methodology is presented, following the assessment is broken down in the individual assessments of surface and groundwater resources availability, the water exploitation index and the standardized precipitation-evapotranspiration index, while at the end of the chapter the overall results are presented. In the fifth chapter of the report, the flood impact assessment methodology is laid down and the individual indicators used are presented while at the end the overall results are presented. In the sixth and last chapter of the report, the methodology for the evaluation of the adaptation measures is presented, while next the results of their evaluation and their effect from their implementation are presented in the form of maps.

2. Impact and adaptation assessment methodology

In the frame of the LIFE UrbanProof project, a methodology was developed for the assessment of water and heat related climate change impacts on the urban environment. The impacts are assessed with respect to the current as well as the projected changes in climate for the emission scenarios RCP4.5 and RCP8.5. At this point, it is considered crucial to present the definitions after IPCC (2014) of certain terms that will be widely used in this report.

Impacts *The term impacts is used primarily to refer to the effects on natural and human systems of extreme weather and climate events and of climate change. Impacts generally refer to 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 time period and the vulnerability of an exposed society or system.*

Hazard *The potential occurrence of a natural or human-induced physical event or trend or 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.*

Exposure *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.*

Vulnerability *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.*

Adaptation *The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects.*

In brief, according to the methodology developed for the assessment of climate change impacts on urban municipalities, the impacts are conceived as a function of the climate change hazards and the vulnerability of the exposed population. The concept is expressed through *Equations 1* and 2 presented below:

$$\boldsymbol{I = (H * V)^{1/2}} \qquad \textbf{(Eq. 1)}$$

and

$$\boldsymbol{V = aV_s * E} \qquad \textbf{(Eq. 2)}$$

Where ***I*** is the impact examined, ***H*** is the hazard, ***V*** is the total vulnerability of the exposed population, ***E*** is the exposure, V_S the social vulnerability and ***α*** the weight of social vulnerability. Each variable of Equations 1 and 2 is an independent indicator consisting of one or more sub-indicators. The hazard indicators are used to reflect the climate dependent information for each impact, the exposure indicators are used to reflect the exposure of population and/or infrastructure to an impact while the social vulnerability indicators are used to reflect population groups sensitive to climate change impacts and the adaptive capacity of the society and its structures. The hazard indicators were calculated with the use of climatic information for the reference period as well as for the projected changes in climate based on the emission scenarios RCP4.5 and RCP8.5.The data were provided by the National Observatory of Athens within the framework of Action C.2 entitled "Simulation of current climate and projection of future changes in climate". Exposure is estimated with the use of spatial data on population (i.e. population density) and on the critical infrastructure (where relevant) while social vulnerability is estimated with the use of relevant statistical data on sensitivity and adaptive capacity indicators. The social vulnerability indicators are combined to form the composite social vulnerability index (for more information see Section 3). Adaptation is considered to reduce the level of impact and therefore the following equation is applied:

$$I_{with\ adaptation} = I_{w/o\ adaptation} - A \qquad \textit{(Eq. 3)}$$

In general, the methodology includes the stages of normalization, weighting and aggregation. In the normalization stage, the values of indicators expressed in different measurement units are adjusted to a common scale, in order to be comparable. The normalization scale for the impact indicators is set within the numerical range 0-5 with the different values expressing five different levels, from low to high as shown in Table 1. The social vulnerability indicator values were normalized based on their position with regard to the respective European average value (above/below average values), an approach which was also applied in Defra (2006). The weighting stage includes the assignment of weights to the variables in order to express the contribution and the relevant importance of each sub-indicator in a composite index. In particular, a weight of 0.4 is assigned to social vulnerability (Vs) in order to reflect its contribution to the overall impact assessment.

Table 1: Rating scale of impact indicators

Qualitative scale	Numerical scale
Low	**$0 < I \leq 1$**
Low to Medium	**$1 < I \leq 2$**
Medium	**$2 < I \leq 3$**

Medium to High	**3 < I ≤ 4**
High	**4 < I ≤ 5**

In Sections 4 and 5 the impacts of water availability, droughts and floods are assessed while in Section 6 the impacts are re-assessed after the implementation of selected adaptation measures.

3. Social vulnerability index

In the frame of the current impact assessment, a composite social vulnerability index was built combining those social indicators considered more relevant for the assessment of the water and flood impact assessments. These indicators refer to population age, chronic illnesses, poverty rate, educational level and hospital beds per inhabitant. The specific indicators are selected because they are considered to reflect the sensitive groups within the population such the elderly and the very young, the low-income people, the illiterate and the people with illnesses, or, to reflect the response capacity through the adequacy of the medical infrastructure within the region (hospital beds). The sensitivity indicators are proportionally related to vulnerability, as the higher the sensitivity the higher the vulnerability, while the adaptive capacity indicators are inversely related to vulnerability, as the higher the adaptive capacity, the lower the vulnerability. The equation used for the calculation of the Social vulnerability index (V_{social}) is as follows:

$$\boldsymbol{V_{social} = \frac{\sum_1^n S}{n}} \qquad \textbf{\textit{(Eq. 4)}}$$

Where *S* is the social indicator and *n* is the number of individual social indicators. The correlation of these indicators with social vulnerability to water and floods is presented following.

3.1. Age

The climate change impacts on water availability may affect the very old people in the case of extremes, e.g. of a prolonged and severe drought where the water supply system is interrupted. A potential reduced physical ability of these people due to aging, is possible to deter them from finding alternative water sources to satisfy their needs (Swart et al., 2012).

With respect to floods, the very young and older people are considered to be less capable of dealing with the impetuous flood forces. In particular, children are particularly vulnerable because they are physically smaller and weaker than adults and are especially susceptible to hypothermia and shock while the very old are more vulnerable to the effects of immersion (Defra, 2006). The elderly and the children are particularly vulnerable to the direct and the indirect health consequences of floods (Hajat et al., 2005). Confused elderly people may be frightened and bewildered by flood warnings (Thrush, 2005) and thus less capable of protecting themselves. The age threshold for the older people was considered to be 70, which may be considered as an average of 65 and 75 age thresholds referred to in Swart et al. (2012) and Defra (2006) respectively. In the case of the very young people, the threshold of 9 years old was used.

The developed indicator refers to the percentage of people over 70 years old plus the percentage of people under 9 years old and is used to account for the increased sensitivity of these groups to the climate change impacts under study. The data are available at municipal level and are sourced from the National Statistical Services of Italy (ISTAT, 2017), Greece (ELSTAT, 2011a) and Cyprus (CYSTAT, 2012) as well as from Eurostat (2017). The percentage values for each municipality were normalized in the scale 0-5 based on their position with regard to the respective European average value (above/below average values), as shown in Table 2.

3.2. Illiteracy

The literacy rate is included as a measure of the adaptive capacity of individuals (World Bank, 1998). Education increases the skills and knowledge to understand risks and increases the ability to protect (Katic, 2017). People with more education have better position to negotiate equitable solutions (Granados, 2012). On the other hand, it may be more difficult for people who cannot read or write to learn and claim, for example, flood government reimbursements for damages to their property. Illiteracy may prevent people from understanding information provided by authorities on the risk of flooding, emergency procedures or preventative/recovery actions (Kazmierczak, 2015).

The indicator created to reflect this population group is actually the percentage of people with educational level lower than primary school, such as illiterate/literate with lack of an official educational level or those who gave up school. The data are available at municipal level and are sourced from the National Statistical Services of Italy (ISTAT, 2011), Greece (ELSTAT, 2011b) and Cyprus (CYSTAT, 2011) as well as from Eurostat (2017). The percentage values for each municipality were normalized in the scale 0-5 based on their position with regard to the respective European average value (above/below average values), as shown in Table 2.

3.3. Low-income

In the cases where water is not affordable for all and especially in times of water shortages when water may become more expensive, the water budget in low-income households may constitute a significant part of the total household budget. Therefore the low-income groups are considered sensitive to water scarcity (Swart et al., 2012).

Low-income people are also particularly vulnerable to the direct and the indirect health consequences of floods (Hajat et al., 2005). Low-income people may be more sensitive to floods because of poorer-quality housing while higher income people may afford to implement flood protection measures and/or may recover more quickly from flood impacts (Katic, 2017).

The indicator created to reflect this population group is actually the percentage of population exposed to poverty risk. This information is available from Eurostat (2016) at national level only and therefore the values assigned to each partner municipality are the respective national ones. The percentage values for each municipality were normalized in the scale 0-5 based on their position with regard to the respective European average value (above/below average values), as shown in Table 2.

3.4. Chronic diseases

The climate change impacts on water availability in the case of extremes, e.g. of a prolonged and severe drought where the water supply system is interrupted, can be particularly stressful for sensitive population groups such as the infirm people and the people with physical disabilities (Swart et al., 2012).

Pre-existing health problems may also negatively affect the capacity of people to react in the event of extreme weather events, such as floods (Rygel et al., 2006). People suffering from chronic health diseases are most prone to post-flood mortality and to flood-related diseases. Finally, flooding may limit access to medicine or to prompt medical care (Swart et al., 2012).

The indicator refers to the percentage of people with chronic diseases (asthma, chronic lower respiratory-excluding asthma, high blood pressure, stroke or chronic stroke disease, diabetes, chronic depression). This information is available from Eurostat (2014) at national level only and therefore the values assigned to each partner municipality are the respective national ones. The percentage values were normalized in the scale 0-5 based on their position with regard to the respective European average value (above/below average values), as shown in Table 2.

3.5. Hospital beds

Flooding events stress hospital capacity as they are suddenly overwhelmed by patients with injuries caused by floods as well with other mental illnesses caused by traumatic experiences from floods (Fernandez et al., 2002). The number of hospital beds may reflect the capacity of a city to treat an increased number of patients due to extreme weather events such as floods (Swart et al., 2012; Katic, 2017). The higher the hospital capacity, the higher the response capacity to emergency events.

The indicator refers to the available hospital beds per capita and is available from Eurostat (2015) at regional level. Therefore the values assigned to each partner municipality are the respective regional ones.

Unlike the previous indicators, this is an adaptive capacity indicator and therefore its normalization is based on an inverse scale, as the greater the number of hospital beds per capita, the lower the vulnerability. In particular, the indicator values were normalized in the scale 5-0 based on their position with regard to the respective European average value (above/below average values), as shown in Table 2.

Table 2: Normalization of social indicator values

$\frac{\text{Municipal/regional/national value}}{\text{European average value}}$	Normalized scale for sensitivity indicators	Normalized scale for adaptive capacity indicators
0.0 – 0.4	0 - 1	5 - 4
0.4 – 0.8	1 - 2	4 - 3
0.8 – 1.2	2 - 3	3 - 2
1.2 – 1.6	3 - 4	2 - 1
1.6 - above	4 - 5	1 - 0

The normalized values for each of the abovementioned indicators are presented below.

Table 3: Normalized values of social indicators

Social indicator	Study area A	Study area B	Study area C
Age (<9 & >70) – municipal level	2.9 (Reggio Emilia)	2.8 (Peristeri)	2 (Strovolos)/ 1.9 (Lakatamia)
Illiteracy level – municipal level	0.9 (Reggio Emilia)	1.8 (Peristeri)	0.7 (Strovolos & Lakatamia)
Poverty risk – national level	3.8 (Italy)	3.9 (Greece)	3 (Cyprus)
Chronic diseases – national level	2.8 (Italy)	2.8 (Greece)	2 (Cyprus)
Hospital beds per inhabitant – NUTS2 level	4 (Emilia-Romagna)	2 (Attica)	3.9 (Cyprus)

4. Water availability & drought impact assessment

For the impact assessment of water availability under climate change a number of commonly accepted indicators was used, such as the Water Exploitation Index (WEI) and the Standardized Precipitation Evapotranspiration Index (SPEI). These indicators are generally used for the presentation of the current situation with respect to water availability but for the purpose of this study, climatic projections on precipitation are used to depict future water availability. In particular, projections on precipitation were used for two different time periods (2031-2060 & 2071-2100) and climate change scenarios (RCP4.5 & RCP8.5), produced in the frame of Action C2 “Simulation of current climate and projection of future changes in climate” of the LIFE UrbanProof project.

Urban municipalities are not usually supplied with water sourced within the municipalities’ boundaries mainly because the water is not enough to meet the demand. Therefore water availability in the frame of the current assessment is assessed at the wider river basin management level where the main domestic water supply sources of the project municipalities are located. The results of the assessment refer to the municipalities as a whole, since water supply is managed at central level and may be used by the competent authorities for investigating whether there will be need for adaptation action, e.g. for promoting water saving measures and/or for augmenting water supply. The hazard and risk indicators used for describing the climate change effect on water resources are presented following:

- **Water Availability**: This indicator quantifies water stress caused by the limited availability of freshwater resources. It is calculated as the sum of surface water and groundwater resources used for potable water supply (see Chapter 4.1). Surface water resources were calculated through the estimation of annual water inflow to reservoirs (see Chapter 4.1.1) and groundwater resources were calculated through the estimation of annual groundwater recharge (see Chapter 4.1.2).

- **Water Exploitation**: The Water Exploitation Index (WEI) relates water availability and water use and compares annual water withdrawal/demand from ground and surface water to the total renewable freshwater resources (see Chapter 4.2). Considering that the calculation of this indicator is based on water availability, it was decided that only WEI will be used for the impact assessment, to avoid double counting.

- **Droughts**: Drought in the frame of this study is measured with the use of the Standardized Precipitation Evapotranspiration Index (SPEI), which constitutes a slight modification of the Standardized Precipitation Index (SPI). The SPI quantifies the precipitation deficit to reflect the impact of drought on the availability of water resources while SPEI takes into account potential evapotranspiration apart from precipitation and therefore is considered more suitable for the assessment of climate change impacts on water resources (see Chapter 4.3).

The assessment of overall water impact was based on the synthesis of the abovementioned hazard and risk indicators with the vulnerability index. The formula used for the assessment of the overall water impact is presented following:

$$\boldsymbol{I_{water}} = [\left(\frac{\sum_1^n W}{n}\right) * \boldsymbol{V}]^{1/2} \qquad \textbf{\textit{(Eq. 5)}}$$

Where I_{water} : Water impact

W: water indicator

n: number of individual water indicators

Impact (I) is calculated according to Equation 2, with the exception that exposure is not taken into account since there is no spatial differentiation to population/infrastructure exposure within the project municipalities, i.e. the whole population of the municipalities is considered to be equally exposed as water supply is managed centrally. The social vulnerability indicators used for the calculation of the composite social vulnerability index in the water impact formula are the age, poverty and health problems (see Section 3). In the sections that follow, detailed information on the calculation of the individual hazard and risk indicators for each study area is presented.

4.1. Water availability

This section refers to the climate change impact assessment of water availability from the freshwater bodies supplying with potable water the partner municipalities. Water availability is dealt separately for surface water and groundwater resources in the following two sections.

4.1.1. Surface water resources

In this section, the quantity of surface water resources under climate change in the future is estimated based on the calculation of annual water inflow to reservoirs. The assessment takes place for the project municipalities that are supplied with drinking water from surface water resources, i.e. the municipalities of Peristeri, Strovolos and Lakatamia. In particular, the main reservoirs supplying Peristeri municipality are Mornos and Evinos located in the hydrological basin of Central Greece (SSW, 2014), while Lakatamia and Strovolos municipalities are mainly supplied from the reservoirs of Kouris, Arminou, Dhypotamou and Lefkaron which are connected to the South Conveyor Water System (WDD, 2014).

In particular, for the estimation of water inflow to reservoirs, data on mean annual precipitation for the reference period and the two future periods under examination (2031-2060, 2071-2100) were used in combination with the reservoir upstream area (watershed area) and the runoff coefficients of each reservoir (see Table 4). The precipitation data for the reference period are from observations of meteorological stations while for the future periods are from outputs of climatic model simulations provided by the National Observatory of Athens. Runoff coefficient formulas were used for the projection of water inflow in the future periods based on the projections on precipitation. The runoff coefficient formulas for each reservoir were developed from the correlation of precipitation measurements with measurements of water inflow to reservoirs for the reference period. The estimation of water inflow is based on the following equation:

$$\boldsymbol{Water\ inflow} = \boldsymbol{Runoff\ coefficient} \times \boldsymbol{Watershed\ area}\ (\boldsymbol{m^2}) \times \boldsymbol{Mean\ annual\ precipitation}\ (\boldsymbol{mm}) \qquad \textbf{(Eq. 6)}$$

Table 4: Precipitation projections, runoff coefficients and watershed area information of main reservoirs

	Reservoirs	Runoff coefficient (1970-2000)	Watershed (km^2) *	Mean annual Precipitation (mm)				
				1970-2000	2031-2060		2071-2100	
					RCP4.5	RCP 8.5	RCP4.5	RCP8.5
GR	Evinou	0.63	352	1197	1202	1035	1125	860
	Mornou	0.38	587	967	976	851	937	711
CY	Kouri	0.18	308	479	416	410	392	294
	Arminou	0.16	116	791	664	643	605	466
	Dhypotamou	0.13	79	482	372	380	343	266
	Lefkaron	0.05	36	577	444	454	410	319

* (WDD, 2009; SSW, 2014)

The results for the area of Greece and Cyprus are presented in Table 5 and Table 6, respectively. In particular for the case of Evinos and Mornos reservoirs, the results of water inflow according to RCP8.5 indicate a reduction of 20-24% the period 2031-2060 and a reduction of 46-49% for the period 2071-2100, while according to RCP4.5 the maximum expected reduction is 11% for the period 2071-2100.

Table 5: Annual water inflow to reservoirs due to rainfall – Central Greece basin

Period	Reservoir	Water Inflow (hm^3)			Change	
			RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
1970-2000	Evinos	269				
	Mornos	252				
	Total	**521**				
2031-2060	Evinos		273	205	1.5%	-24.0%
	Mornos		263	202	4.5%	-19.7%
	Total		**536**	**407**	**2.9%**	**-21.9%**
2071-2100	Evinos		241	138	-10.6%	-48.8%

Period	Reservoir	Water Inflow (hm^3)			Change	
			RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
	Mornos		243	137	-3.4%	-45.7%
	Total		**484**	**275**	**-7.1%**	**-47.3%**

For the case of Cyprus' reservoirs, significant reductions are expected for both climate change scenarios. In particular, according to RCP4.5 a reduction of 24-48% and 35-59% is expected during the periods 2031-2060 and 2071-2100, respectively. Based on RCP8.5 the reduction is higher for the period 2071-2100 ranging from 63 to 76%. In all cases, the higher reduction is expected for the case of Lefkara reservoir.

Table 6: Mean annual inflow to reservoirs due to rainfall – South Conveyor System, Cyprus

Period	Reservoir	Mean annual water inflow (hm3)			Change	
			RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
1970-2000	Kouri	31.9				
	Arminou	17.1				
	Dhypotamou	5.1				
	Lefkaron	1.5				
	Total	**55.6**				
2031-2060	Kouri		24.3	24.2	-23.8%	-24.1%
	Arminou		11.3	10.3	-34.0%	-39.6%
	Dhypotamou		2.8	3.0	-45.2%	-41.2%
	Lefkaron		0.8	0.9	-47.8%	-43.3%
	Total		**39.2**	**38.4**	**-29.5%**	**-31.0%**
2071-2100	Kouri		20.6	11.8	-35.3%	-63.0%
	Arminou		8.4	4.5	-51.1%	-73.5%
	Dhypotamou		2.3	1.4	-55.7%	-72.9%
	Lefkaron		0.6	0.4	-58.6%	-75.5%
	Total		**32.6**	**18.5**	**-42.6%**	**-67.5%**

If the actual contribution of each reservoir in drinking water supply for the wider case study areas (Attica region, Lefkosia district) is taken into consideration according to the current water management system (Table 7), the annual surface water availability for drinking water in the study areas is estimated, as may be seen in Table 8 and Table 9.

Table 7: Contribution of water bodies in drinking water for the case study areas

	Reservoirs	Contribution (%)
Central Greece basin, Greece (supply to Greater Metropolitan area of Athens)	Evinos	**81**
	Mornos	**83**
South Conveyor System, Cyprus (supply to Lefkosia district)	Kouris	**30**
	Arminou	**30***
	Dipotamou	**86**
	Lefkaron	**85**

** Water from Arminou reservoir is transferred to Kouris reservoir through Diarizos diversion and then distributed for consumption, therefore the same rates are applied*

In particular, for the case of central Greece basin which supplies the Greater Metropolitan area of Athens with drinking water, a reduction of 22% and 47% in drinking water availability is estimated according to RCP8.5 for the periods 2031-2060 and 2071-2100 respectively, while according to RCP4.5 no significant changes are observed.

Table 8: Mean annual surface water availability for drinking water – Central Greece basin

Period	Mean annual drinking water availability (hm^3)		Change in drinking water availability (%)	
	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
1970-2000	429			
2031-2060	442	335	2.9%	-21.9%
2071-2100	399	226	-7.1%	-47.3%

For the case of the South Conveyor System reservoirs which supply the district of Lefkosia with drinking water, a reduction in drinking water availability of 32-33% is estimated for the period 2031-2060 for both scenarios while for the period 2071-2100 the reduction rises up to 45% according to RCP4.5 and to 69% according to RCP8.5, resulting in a water availability quantity approximately one third of that estimated for the baseline situation.

Table 9: Mean annual surface water availability for drinking water - South Conveyor System, Cyprus

Period	**Mean annual drinking water availability (hm3)**		**Change in drinking water availability**	
	RCP 4.5	**RCP 8.5**	**RCP 4.5**	**RCP 8.5**
1970-2000	20.5		-	
2031-2060	13.8	13.7	-32.4%	-32.9%
2071-2100	11.2	6.4	-45.1%	-68.5%

4.1.2. Groundwater resources

In this section, the future quantity of groundwater resources under climate change is estimated based on the calculation of annual groundwater recharge. The assessment takes place for the project municipalities that are supplied with drinking water mainly from groundwater resources, i.e. the municipality of Reggio Emilia in Italy. Groundwater reserves in the area are quite extensive and natural recharge depends on a number of hydrogeological systems located in the wider area of Emilia-Romagna region. The natural recharge of these systems is connected with the hydrogeological balance of other large and complex systems located in the Apennine and River Po basin. To limit the boundaries of the current analysis, the aquifer of Enza river was selected for further examination as it is the aquifer where the most of the wells are located. In particular, six of the seven main wells providing Reggio Emilia’s aqueduct with water are located in aquifer of river Enza, as shown in Figure 1.

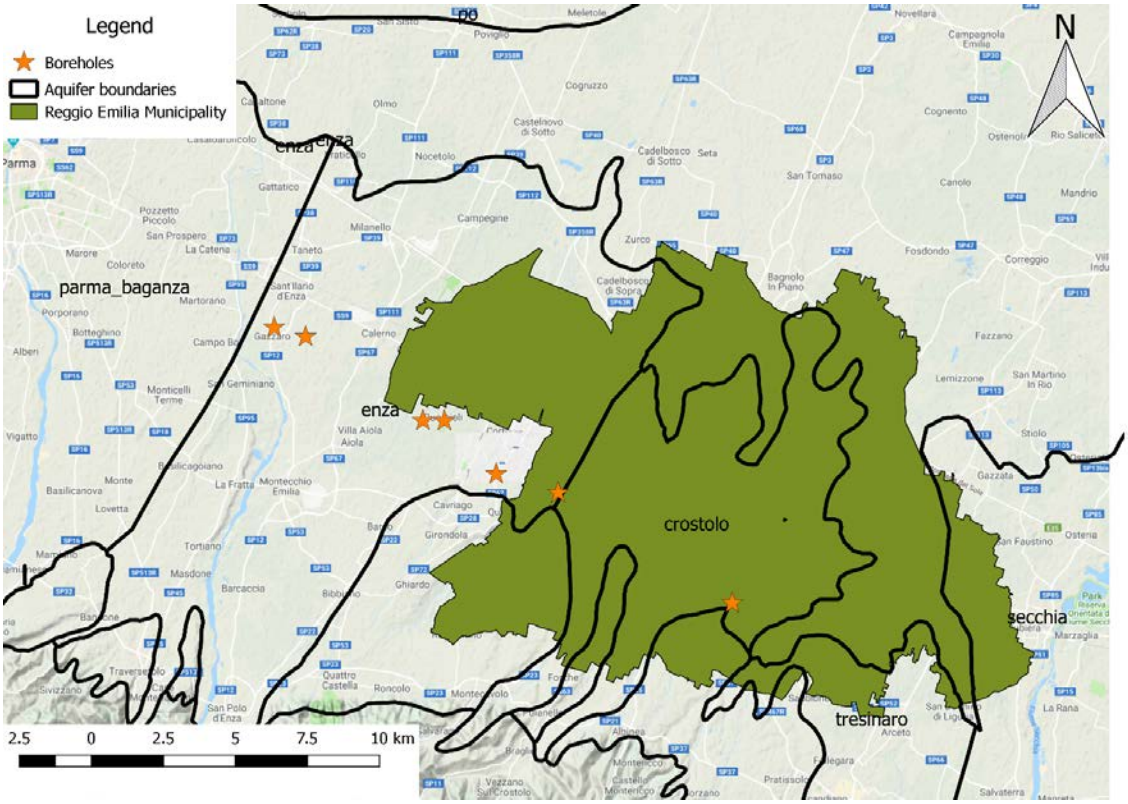

Figure 1: Wells location in Enza river aquifer

Two types of groundwater recharge are examined, recharge by infiltration and recharge by river bed seepage (stretch S.Polo-S.Ilario). There is also another groundwater recharge type, that of recharge by irrigation, but it was not examined in the current study because it is not climate dependent.

Recharge by infiltration was estimated with the use of an infiltration coefficient of 22% (Marletto et al., 1993) based on precipitation data for an area of 131km^2 which corresponds to the total area of the Enza river alluvial fan (Barbieri and Martinelli, 2007). Recharge by river bed seepage was calculated with the use of a coefficient of 23% which was calculated based on river flow timeseries and on an average groundwater recharge quantity due to river bed seepage of 15.7*10^6 m3/y provided by Barbieri and Martinelli (2007). River flow timeseries for the examined future periods were estimated with the use of precipitation timeseries for the future periods and the rainfall-river flow relationship built on available data from the baseline period. The total annual groundwater recharge is calculated with the following equations:

$$\textit{Annual groundwater recharge} = \textit{Recharge by infiltration} + \textit{Recharge by river bed seepage} \quad \textbf{(Eq. 7)}$$

$$Recharge\ by\ infiltration = infiltration\ coefficient\ \times mean\ annual\ rainfal\ (mm) \times aquifer\ area\ (m^2) \quad \textit{(Eq. 8)}$$

$$Recharge\ by\ river\ bed\ seepage\ =\ seepage\ coefficient \times river\ flow\ (m^3/s) \times 3.15E+06\ (s/y) \quad \textit{(Eq. 9)}$$

According to Table 10 where the results of the analysis are presented, no significant changes in groundwater recharge are expected for the case of river Enza aquifer for any of the climate change scenarios and periods examined. In particular, the greater change is expected for the period 2071-2100 and it refers to a reduction of 8% in annual groundwater recharge according to the scenario RCP4.5.

Table 10: Annual groundwater recharge of Enza r. aquifer – Reggio Emilia (in hm3)

	1970-2000	2031-2060		2071-2100	
		RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Infiltration	26.4	26.2	26.5	24.5	25.6
River bed seepage	15.7	15.6	15.8	14.4	15.2
Total	42.1	41.8	42.3	38.9	40.7
Change compared to 1970-2000	-	-1%	1%	-8%	-3%

4.2. Water Exploitation

The Water Exploitation Index (WEI) relates water availability and water use and compares annual water withdrawal/demand from ground and surface water resources to the total renewable water resources. In particular, WEI is defined as the ratio of annual water withdrawal to the total freshwater resources. Total freshwater resources are calculated in the frame of this study as the average annual storage of water in the water bodies examined plus the total annual inflow to the water bodies, according to the following equation:

$$\boldsymbol{WEI = \frac{Total\ annual\ withdrawals}{Average\ annual\ storage + Total\ annual\ inflow}} \qquad \textit{(Eq. 10)}$$

The baseline WEI is calculated based on the available data for annual inflow, abstractions and storage. Future abstractions are calculated on an annual basis based on the average water abstractions per capita for the baseline period which is multiplied with the projected population for a given year in the future. In that sense, water demand patterns are considered constant for the future periods while total abstractions change proportionally to population changes.

$$\boldsymbol{Future\ annual\ withdrawals = Average\ annual\ withdrawals\ per\ capita \times Projected\ future\ population} \qquad \textit{(Eq. 11)}$$

The population taken into account for each area is the population served by the drinking water supply system examined, i.e. the population of Lefkosia district for the reservoirs of the Southern Conveyor system in Cyprus, the population of Attica region for the Central Greece basin system and the population of the Reggio Emilia province for the case of the Enza aquifer water supply system. The population projections are sourced from Eurostat (2018) and are developed based on specific assumptions for fertility, mortality and net migration with the use of the "cohort-component" method. Considering that Eurostat provides population projections at national level only, the national population projection trends for the three countries are applied at the respective regional populations under examination. The population data used in the current study are presented in brief in the following table.

Table 11: Population data for the examined areas and periods (averages)

Area		**1985-2015**	**2031-2060***	**2071-2100***
Lefkosia district	Absolute number	301,490	378,377	388,265
	% change	-	26%	29%

Attica region	Absolute number	3,855,471	2,914,653	2,484,663
	% change	-	-24%	-36%
Reggio Emilia province	Absolute number	457,934	517,583	465,957
	% change	-	13%	2%

** Based on population projections available at national level*

As it may be observed from the table above, the population of Lefkosia district is expected to increase in the future by 26-29% compared to the baseline period and the population of Reggio Emilia province is also expected to increase in the near future (2031-2060) by 13% while for the long-term future (2071-2100) there will be no significant change compared to the current period. On the other hand, the population of the Attica region is expected to decrease by 24% in the near future and by 36% in the long-term future.

Future annual inflow to the examined water bodies is estimated in Section 4.1: Water availability. Future storage is calculated on an annual basis based on the data for the latest year available where the annual water balance is added. The latter is calculated as the annual inflow minus the annual abstractions. The relevant equations are presented next:

$$Storage_n = Storage_{n-1} + Annual\ balance_n \quad \text{(Eq. 12)}$$

$$Annual\ water\ balance = Annual\ inflow - Annual\ withdrawals \quad \text{(Eq. 13)}$$

where n is the year for which water storage is calculated. In the case that the calculation of water storage becomes negative, either due to a decrease in inflow and/or to an increase in the withdrawals, storage is considered equal to zero and water demand is considered to be satisfied only by annual inflow. In the tables that follow, the results of the analysis for each water body and in total are presented separately for each area.

In particular, for the case of Lefkosia district (Table 12) the WEI for the baseline period is already high (91-94%) for all relevant reservoirs, meaning that available water resources barely satisfy water demand. As water storage is relatively low in all relevant reservoirs, the foreseen decrease in annual inflow due to climate change and the increase in withdrawals due to population increase will result in the depletion of water stored in the reservoirs and to inability to satisfy a significant part of water demand. In specific, the WEI of the 2031-2060 period ranges between 150-200% while the WEI of the 2071-2100 period reaches up to 406% for the scenario RCP8.5, meaning that the water demand will be more than four times greater than the available water resources. However, it should be noted here that Cyprus also depends on a great extent on desalination for satisfying demand in drinking water and therefore a reduction in freshwater availability is currently overcome with an increase in desalination water supply. In any case, the projected increase in WEI calls for direct response in order to face significant shortcomings in drinking water demand satisfaction from the available freshwater resources.

Table 12: Water exploitation index, Lefkosia district (in hm^3)

Water body	Indicator	1989-2017	2031-2060		2071-2100	
			RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Kouris reservoir	Total inflow	698	579	577	492	282
	Total abstractions	668	1115		1144	
	Average storage	35	0	0	0	0
	WEI	**91%**	**193%**	**193%**	**233%**	**406%**
Arminou reservoir (1999-2017)	Total inflow	333	394	353	292	155
	Total abstractions	315	605		620	
	Average storage	1.4	0.0	0.1	0.0	0.0
	WEI	**94%**	**153%**	**171%**	**212%**	**400%**
Lefkara reservoir	Total inflow	79	60	60	48	26
	Total abstractions	75	102		105	
	Average storage	4.2	0.0	0.3	0.0	0.0
	WEI	**91%**	**170%**	**168%**	**220%**	**402%**
Dipotamos reservoir	Total inflow	149	116	96	94	54
	Total abstractions	143	197		202	
	Average storage	4.9	0.0	0.1	0.0	0.0

Water body	Indicator	1989-2017	2031-2060		2071-2100	
			RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
	WEI	**92%**	**169%**	**205%**	**215%**	**377%**
Total	Total inflow	1259	1150	1087	926	517
	Total abstractions	1200	2019		2071	
	Average storage	45.6	0.0	0.5	0.0	0.0
	WEI	**92%**	**176%**	**186%**	**224%**	**401%**

For the case of Attica region (Table 13) the WEI for the baseline period is also high (94-96%) for both reservoirs, while according to RCP4.5 the WEI for both future periods will decrease to 36-72%. According to RCP8.5, the WEI for the case of Evinos reservoir will increase up to 118% while for the case of Mornos reservoir it will slightly decrease. It is also noted that the water reserves of Evinos reservoir are expected to be depleted for a number of years in both periods according to RCP8.5.

Table 13: Water exploitation index, Attica region (in hm³)

Water body	Indicator	Baseline period	2031-2060		2071-2100	
			RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Mornos reservoir (1985-2016)	Total inflow	7,462	7,588	5,756	7,015	3,888
	Total abstractions	7,475	5,528		4,283	
	Average storage	449	1,566	397	4,903	860
	WEI	**94%**	**60%**	**90%**	**36%**	**90%**
Evinos reservoir (2002-2016)	Total inflow	3,795	7,721	5,825	6,803	3,923
	Total abstractions	3,720	6,093		4,722	
	Average storage	62	750	41	3,357	82

Water body	Indicator	Baseline period	2031-2060		2071-2100	
			RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
	WEI	**96%**	**72%**	**104%**	**46%**	**118%**
Total	Total inflow	11,256	15,309	11,582	13,818	7,811
	Total abstractions	11,194	11,621		9,005	
	Average storage	598	2,316	438	8,260	942
	WEI	**94%**	**66%**	**97%**	**41%**	**103%**

For the case of the Reggio Emilia province and the Enza aquifer (Table 14), the WEI for the baseline period is 60%, while for the period 2031-2060 it will increase up to 109% and for the 2071-2100 period it will further increase up to 164%. As it is also mentioned above, a WEI between 100-200% means that a part of the water demand will not be able to be satisfied from the available water resources. Considering that both the Attica region and the Reggio Emilia province depend on these water bodies for the majority of their drinking water supply, there will be need to increase their preparedness in order to face reduced freshwater availability through the reduction in water demand and/or the exploration of additional water resources.

Table 14 : Water exploitation index, Reggio Emilia province (in hm^3)

Water body	Indicator	1982-2014	2031-2060		2071-2100	
			RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Enza aquifer	Total inflow	1,316	1,255	1,270	1,167	1,222
	Total abstractions	2,053	2,140		1,927	
	Average storage	2,091	758	686	4.6	0.3
	WEI	**60%**	**106%**	**109%**	**164%**	**158%**

The WEI values are normalized according to the classification scale presented in Table 15, in order to be used in the water impact assessment. The normalized WEI values are presented in summary in Table 16.

Table 15: Classification of WEI results

Range	Class
[0% - 30%)	1
[30% - 50%)	2
[50% - 70%)	3
[70% - 90%)	4
≥90%	5

Table 16: Normalized WEI values

Area	Baseline period	2031-2060		2071-2100	
		RCP4.5	RCP8.5	RCP4.5	RCP8.5
Lefkosia district	4.3	4.5	4.5	4.6	5.0
Attica region	4.3	3.0	4.3	1.9	4.3
Reggio Emilia province	2.9	4.3	4.3	4.4	4.4

4.3. Droughts

Droughts occur due to lack of precipitation and may be categorized to meteorological, agricultural, hydrological and socio-economic droughts according to Dracup et al. (1980). Meteorological droughts are commonly used, inter alia, as indicators to reflect the impacts of water scarcity on urban systems although they do not have a direct impact on them, because they precede the other types of droughts having a direct impact on urban systems (Swart et al., 2012). The Standardized Precipitation Index (SPI) is one of the most widely used indicators to characterize meteorological droughts. The SPI compares total precipitation received at a location during a specific period of months with the long-term precipitation distribution for the same location (McKee et al. 1993). The data needed for its calculation is monthly precipitation timeseries of at least 30 years. The SPI may be calculated for different timescales, i.e. 3-, 6-,12-, 24- and 48-month timescales, with the shorter timescales reflecting drought impacts on soil moisture, the 12-month timescale depicting impacts on streamflow and reservoir storage while the longer timescales (24-48 month timescales) are considered to reflect impacts on groundwater recharge (Svoboda et al. 2012). According to the classification system on SPI proposed by McKee et al. (1993), the SPI takes values between +2 and -2, with the negative values indicating different levels of drought intensity.

However, as also noted by Svoboda et al. (2012), SPI is not the most appropriate indicator for assessing climate change related drought impacts, since it does not take into account temperature and potential evapotranspiration which also have significant effect on droughts. Therefore, a slightly modified SPI was used, the Standardized Precipitation Evapotranspiration Index (SPEI) (Vicente-Serano et al. 2010), which takes into account potential evapotranspiration in addition to precipitation. Thus the SPEI enables identification of drought in the context of climate change. SPEI may be calculated for different timescales like SPI and is classified based on the same scale suggested for SPI (McKee et al. 1993).

For the aims of the current study, the SPEI was calculated with the use of monthly precipitation and evapotranspiration data timeseries from representative locations of each area for the period 1970-2100. The timeseries are actually a compilation of observation timeseries from the reference period (1970-2015) and data produced from climate change projections until the year 2100. Considering that SPEI (like SPI) is useful for assessing drought conditions for a given period and location compared to the long-term precipitation of this location, it is not recommended for comparing the results for different climate change scenarios but for different periods. Therefore, only one climate scenario was selected for examination, that of RCP4.5. All necessary data for SPEI calculation were provided by the National Observatory of Athens.

Calculation of SPEI was made with the use of the SPEI R package software which is available for free in the web repository of the Spanish National Research Council (website address http://digital.csic.es/handle/10261/10002).

SPEI was calculated with the use of climatic data from represenative locations of the water reservoirs supplying with domestic water Lefkosia district in Cyprus (Kouri, Arminou, Dipotamou, Lefkara) and the Greater Metropolitan Athens area in Greece (Mornos, Evinos) as well as for the aquifer of Enza which supplies domestic water the municipality of Reggio Emilia in Italy. The 12-timescale was selected as most suitable for the calculation of SPEI for the water reservoirs of Cyprus and Greece while for the aquifer in Italy, the 24-timescale was selected which is considered to best reflect drought impacts on groundwater recharge. In the figures that follow, the SPEI results for each water body are presented.

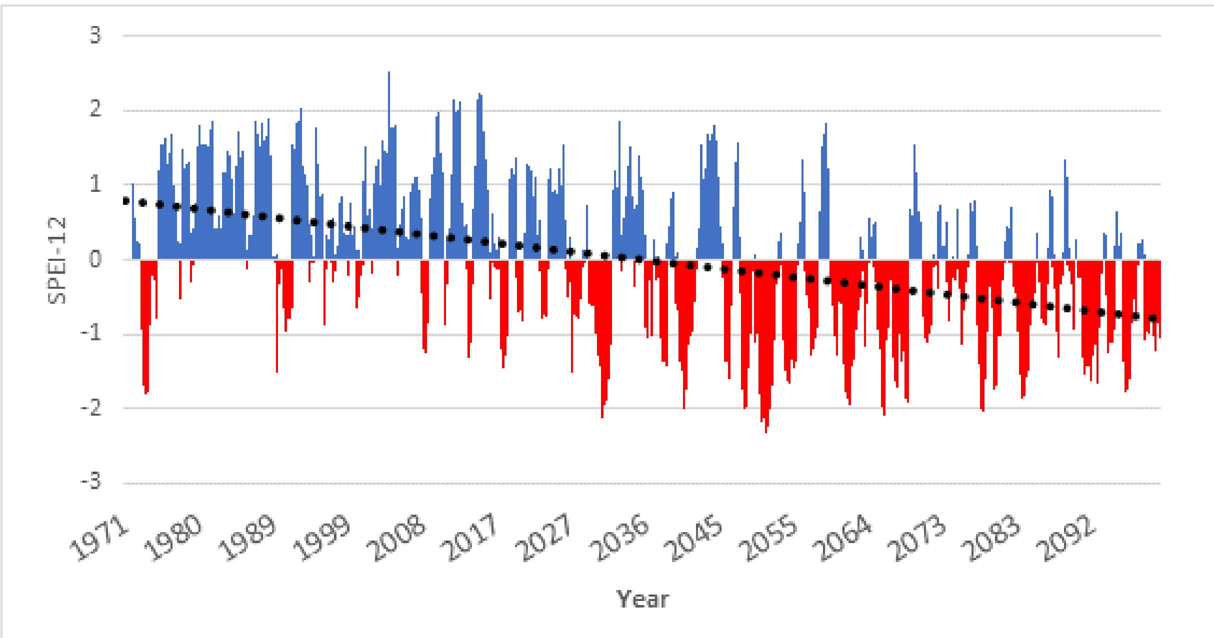

Figure 2: SPEI-12 for the Cyprus' reservoirs Kouri, Arminou, Lefkaron and Dipotamou (1970-2100)

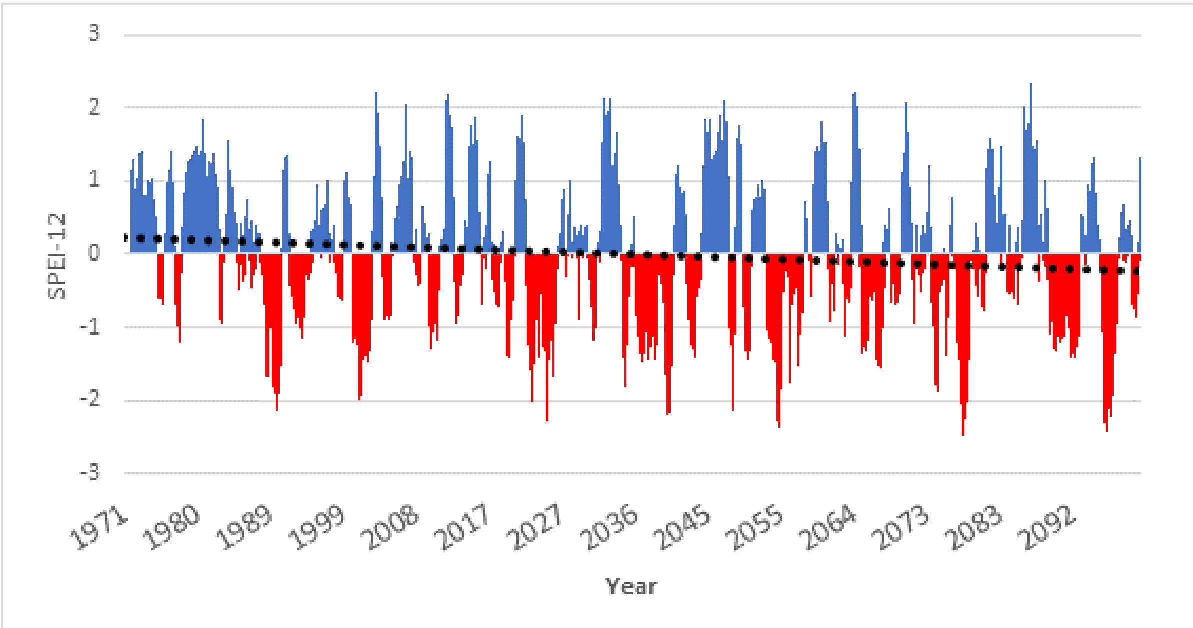

Figure 3: SPEI-12 for the Central Greece basin reservoirs of Mornos and Evinos (1970-2100)

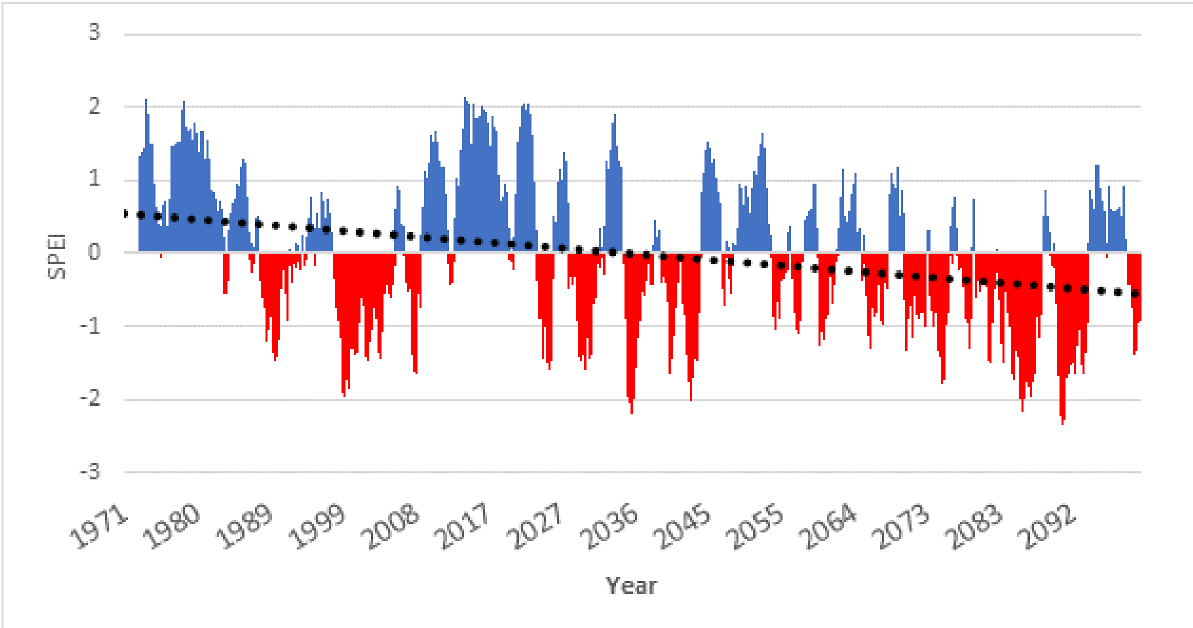

Figure 4: SPEI-24 for the aquifer of Enza in the Emilia-Romagna region, Italy (1970-2100)

To better reflect drought risk two terms were used, that of drought intensity and frequency. Drought intensity is classified based on McKee et al. (1997), while the first class of mild drought was further broken down into two individual classes in order for all classes to be of equal size and at the same time to turn into a five class system without any further need for normalization (see Table 17). To calculate overall drought intensity (DI_t) for a given period and location, the following formula was used:

$$\textbf{Overall drought intensity}, DI_t = \frac{\sum DF_i \times W_i}{\sum W_i} \qquad \textbf{(Eq. 14)}$$

Where *DF* refers to the drought frequency for a specific drought level *i* expressed as the number of months characterized with the specific drought level to the total number of months with drought (negative SPEI values) for the given period, *i* corresponds to the different drought classes A-E presented in Table 17 and *W* is the weight applied to each drought class. As can be seen in Table 17, increasing weights are applied to each drought class according to the level of drought in order to place emphasis on high drought levels. Drought frequency values for the different drought classes, DF_i, are expressed as percentages and then normalised to the 5-degree scale presented in Table 18. Finally, drought risk is estimated with the following formula:

$$\textbf{Drought risk}, DR = \sqrt{DI_t \times DF_t} \qquad \textbf{(Eq. 15)}$$

where DF_t refers to overall drought frequency and is calculated as the total number of months with drought (negative SPEI values) to the total number of months for the given period. It is firstly expressed as a percentage and then normalized with the use of the general scale for the normalization of percentage values provided in Table 19.

Table 17: Drought intensity classification and weighting

Drought intensity	Class	From	To	Weight
Mild drought	A	0	-0.49	1
	B	-0.5	-0.99	2
Moderate drought	C	-1	-1.49	3
Severe drought	D	-1.5	-1.99	4
Extreme drought	E	-2	<-2	5

Table 18: Drought frequency (DFi) normalization, classes A-E

Drought frequency		Normalized classes	
From	To	From	To
0.0%	5.0%	0	1
5.0%	10.0%	1	2
10.0%	15.0%	2	3
15.0%	20.0%	3	4
20.0%	100.0%	4	5

Table 19: Overall drought frequency (DFt) normalization

Drought frequency		Normalized classes	
From	To	From	To
0.0%	20.0%	0	1

20.0%	40.0%	1	2
40.0%	60.0%	2	3
60.0%	80.0%	3	4
80.0%	100.0%	4	5

The drought assessment results for the water bodies of the three countries supplying with domestic water the project municipalities are presented in Table 20, Table 21 and Table 22. In general, one may observe that overall drought intensity has an increasing trend with the exception of Cyprus and Greece during the period 2071-2100 where drought intensity slightly decreases compared to the period 2031-2060. Overall drought frequency has an increasing trend in all examined water bodies throughout the time periods. The overall results for the case of Cyprus show “low to moderate” drought risk (1.4) for the baseline scenario, “moderate” risk (2.9) for the period 2031-2060 and “moderate to high” risk (3.5) for the period 2071-2100. The results for the case of Greece show “moderate” drought risk for the baseline period and for the two future periods (2.0-2.5). Finally, the results for the case of Italy show “low to moderate” drought risk (1.9) for the baseline scenario and “moderate” risk (2.3-2.9) for the two future periods. It should be noted here that the results are useful for comparing drought risk levels between different periods of the same location and not between different locations. The change of drought risk in the future periods compared to the baseline period (Table 23), is very high for the case of the South Conveyor system where drought risk is almost double for both future periods (92-95% increase). Furthermore, a significant increase is also observed during the period 2071-2100 for the case of Enza aquifer (57%) while lower increases of about 28% are also observed for all other cases.

Table 20: Drought assessment results, South Conveyor system (Cyprus)

Drought class, i	Drought frequency, Df_i	1970-2000	2031-2060	2071-2100
[A] 0 to -0.49	**Months**	58	58	98
	Share	64.4%	27.6%	39.4%
	Normalized	4.6	4.1	4.2
[B] -0.5 to -0.99	**Months**	22	40	69
	Share	24.4%	19.0%	27.7%
	Normalized	4.1	3.8	4.1
[C] -1 to -1.49	**Months**	2	69	48
	Share	2.2%	32.9%	19.3%
	Normalized	0.4	4.2	3.9
	Months	8	29	33

[D] -1.5 to -1.99	Share	8.9%	13.8%	13.3%
	Normalized	1.8	2.8	2.7
[E] ≤ 2	Months	0	14	1
	Share	0.0%	6.7%	0.4%
	Normalized	0.0	1.3	0.1
Overall drought intensity, DIt (norm.)		**1.6**	**2.5**	**2.1**
Overall drought frequency, DFt (%)		25%	58%	69%
Overall drought frequency, DFt (norm.)		**1.3**	**2.9**	**3.5**
Drought risk, DR		**1.4**	**2.7**	**2.7**

Table 21: Drought assessment results, Central Greece basin (Greece)

Drought class, i	Drought frequency, Df_i	1970-2000	2031-2060	2071-2100
[A] 0 to -0.49	Months	81	49	72
	Share	53.3%	25.7%	35.5%
	Normalized	4.4	4.1	4.2
[B] -0.5 to -0.99	Months	37	57	58
	Share	24%	30%	29%
	Normalized	4.1	4.1	4.1
[C] -1 to -1.49	Months	18	61	44
	Share	11.8%	31.9%	21.7%
	Normalized	2.4	4.1	4.0
[D] -1.5 to -1.99	Months	14	14	11
	Share	9.2%	7.3%	5.4%
	Normalized	1.8	1.5	1.1
[E] ≤ 2	Months	2	10	18
	Share	1.3%	5.2%	8.9%
	Normalized	0.3	1.0	1.8
Overall drought intensity, DIt (norm.)		**1.8**	**2.4**	**2.2**
Overall drought frequency, DFt (%)		42%	53%	57%
Overall drought frequency, DFt (norm.)		**2.1**	**2.7**	**2.8**
Drought risk, DR		**2.0**	**2.5**	**2.5**

Table 22: Drought assessment results, Enza aquifer (Italy)

Drought class, i	Drought frequency, Df_i	1970-2000	2031-2060	2071-2100
[A] 0 to -0.49	Months	75	90	68
	Share	52.1%	46.2%	27.5%
	Normalized	4.4	4.3	4.1
[B] -0.5 to -0.99	Months	24	49	76
	Share	17%	25%	31%
	Normalized	3.3	4.1	4.1
[C] -1 to -1.49	Months	33	32	48
	Share	22.9%	16.4%	19.4%
	Normalized	4.0	3.3	3.9
[D] -1.5 to -1.99	Months	12	18	46
	Share	8.3%	9.2%	18.6%
	Normalized	1.7	1.8	3.7
[E] ≤ 2	Months	0	6	9
	Share	0.0%	3.1%	3.6%
	Normalized	0.0	0.6	0.7
Overall drought intensity, DIt (norm.)		**1.8**	**2.0**	**2.4**
Overall drought frequency, DFt (%)		39%	55%	70%
Overall drought frequency, DFt (norm.)		**1.9**	**2.8**	**3.5**
Drought risk, DR		**1.9**	**2.3**	**2.9**

Table 23: Change in drought risk compared to the reference period 1970-2000, % (normalized value)

Area	2031-2060	2071-2100
South Conveyor system	95% (5.0)	92% (4.9)
Central Greece basin	28% (1.9)	28% (1.9)
Enza aquifer	27% (1.9)	57% (3.0)

4.4. Water availability and drought impact assessment results

In the current section, the results of the previous sections are synthesized so as to calculate overall water impact based on Equation 3. As it may be seen in Table 24, the highest impact on water resources is expected for the case of Cypriot municipalities as they gather the highest score (5.0) in all future periods and scenarios. The climate change impact on water resources for Peristeri municipality is expected to be "moderate to high" (3.9) in all examined cases apart from the period 2031-2060 and RCP8.5 where the impact is expected to be "moderate" (2.4). The impact for Reggio Emilia municipality is expected to be "moderate to high" (3.7-3.9) in all cases apart from the period 2071-2100 and RCP4.5 where the impact is estimated to be "high" (4.6).

Table 24: Summarized results for the water availability and droughts impact

Municipality	RCP	Period							
		2031-2060				2071-2100			
		WEI	DR	V	I_w	WEI	DR	V	I_w
Strovolos & Lakatamia	**4.5**	4.5	5	1.17	**5.0**	5	4.9	1.17	**5.0**
	8.5	4.6	5	1.17	**5.0**	4.2	4.9	1.17	**5.0**
Peristeri	**4.5**	4.3	1.9	1.25	**3.9**	4.3	1.9	1.25	**3.9**
	8.5	1.9	1.9	1.25	**2.4**	4.3	1.9	1.25	**3.9**
Reggio Emilia	**4.5**	4.3	1.9	1.25	**3.9**	4.4	3	1.25	**4.6**
	8.5	4.4	1.9	1.25	**3.9**	2.9	3	1.25	**3.7**

Following, the impact assessment results for water resources are presented in the form of maps.

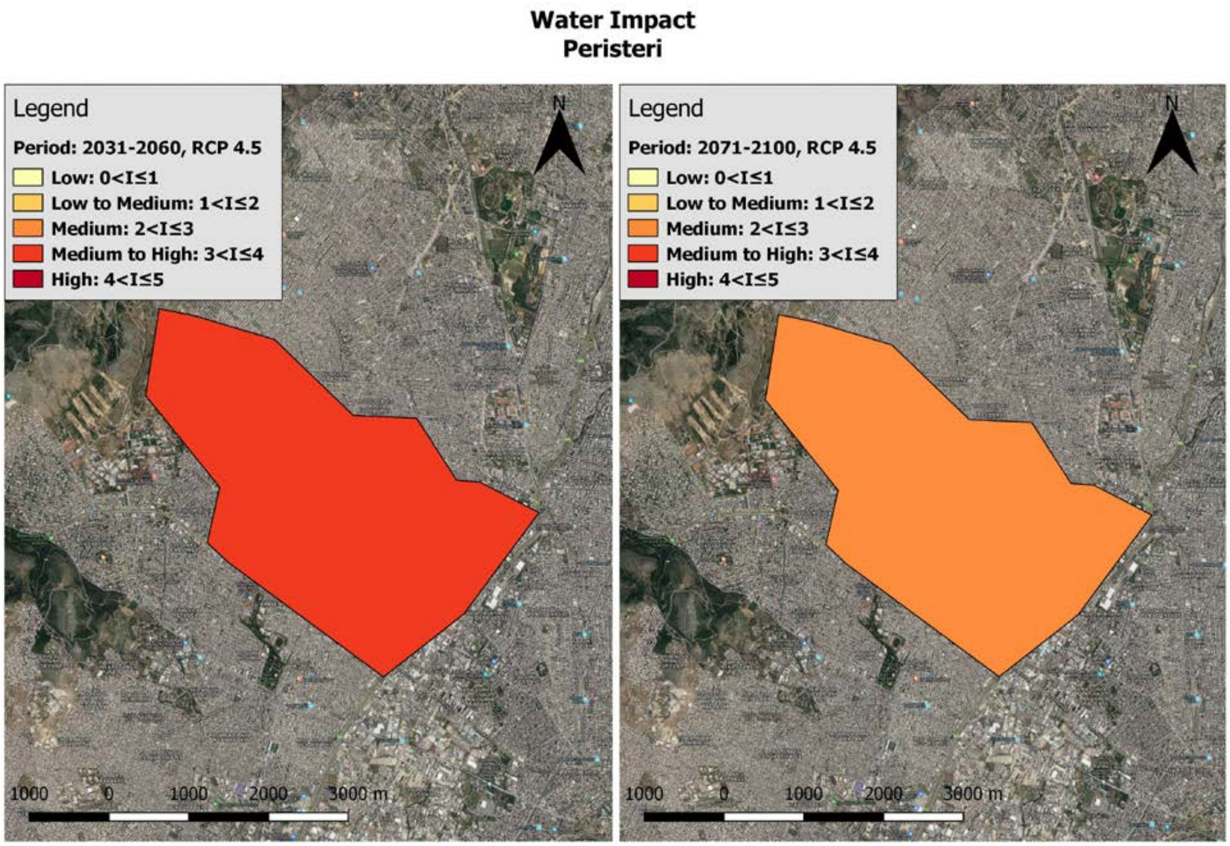

Figure 5: Water impact maps of Peristeri for scenario 4.5. Time period 2031-2060 (left) and time period 2071-2100 (right)

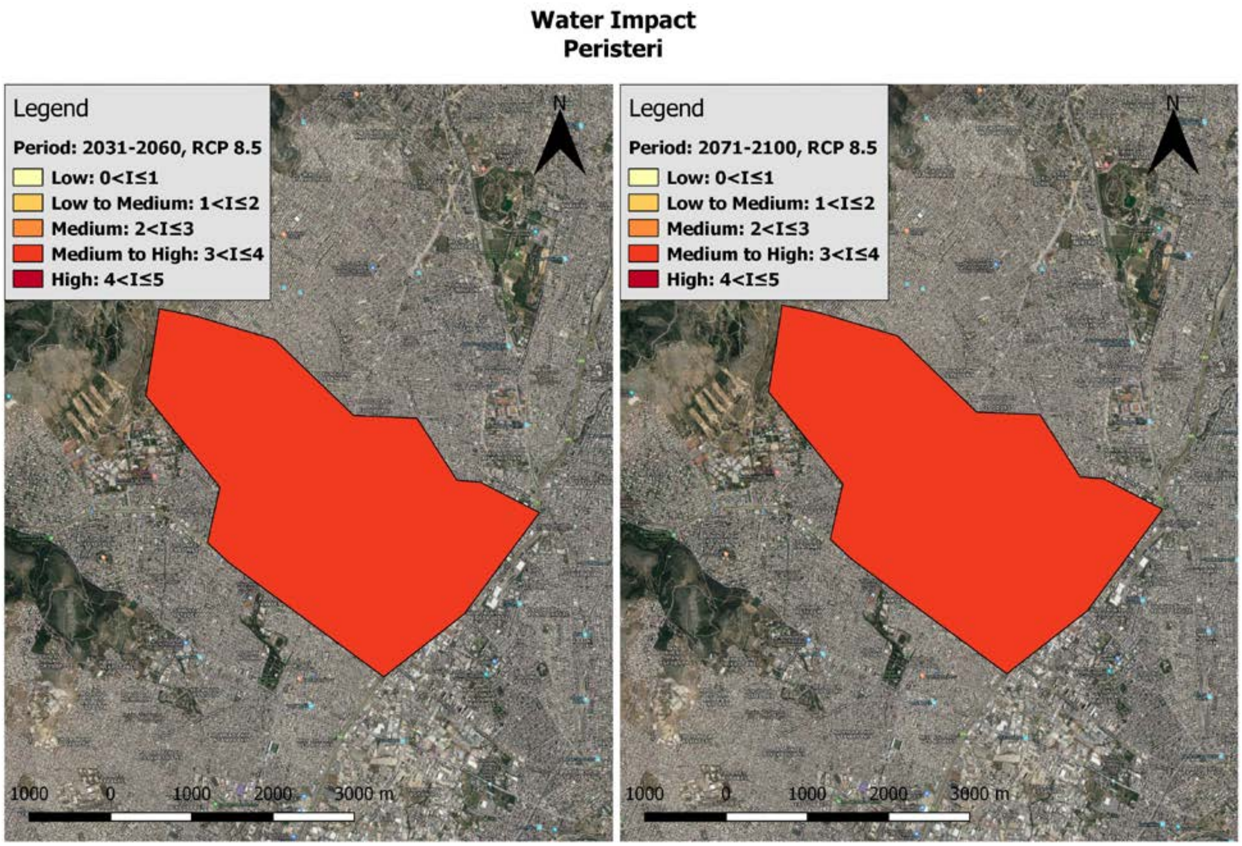

Figure 6: Water impact maps of Peristeri for scenario 8.5. Time period 2031-2060 (left) and time period 2071-2100 (right)

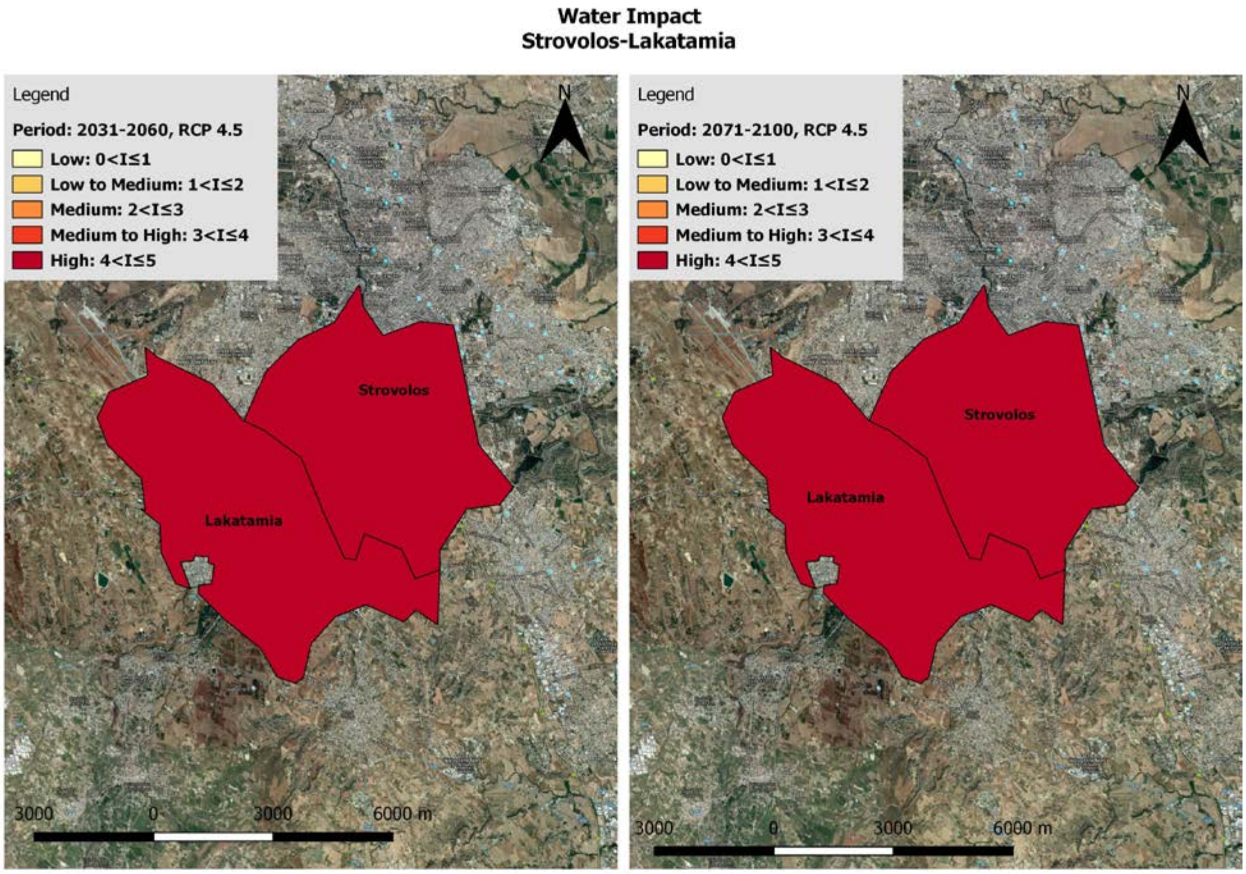

Figure 7: Water impact maps of Strovolos and Lakatamia municipalities for scenario 4.5. Time period 2031-2060 (left) and time period 2071-2100 (right)

Water Impact
Strovolos-Lakatamia

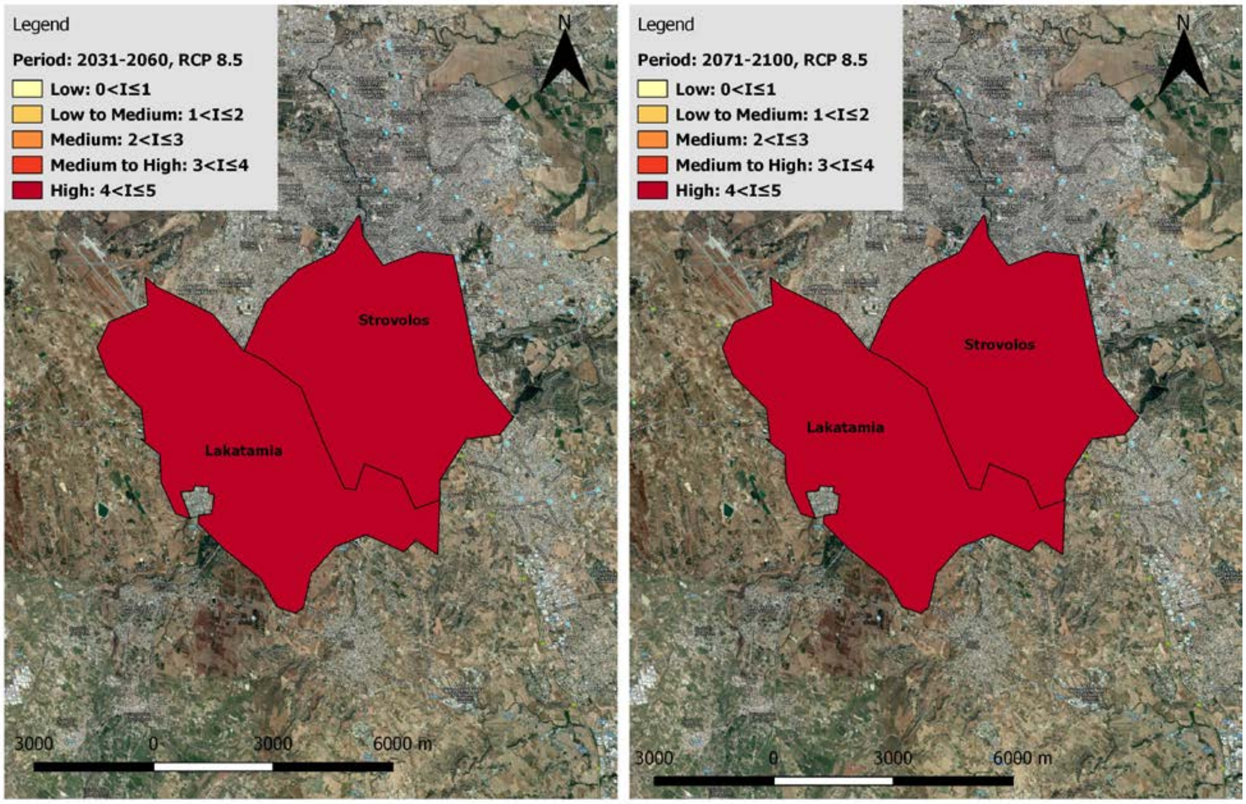

Figure 8: Water impact maps of Strovolos and Lakatamia municipalities for scenario 8.5. Time period 2031-2060 (left) and time period 2071-2100 (right)

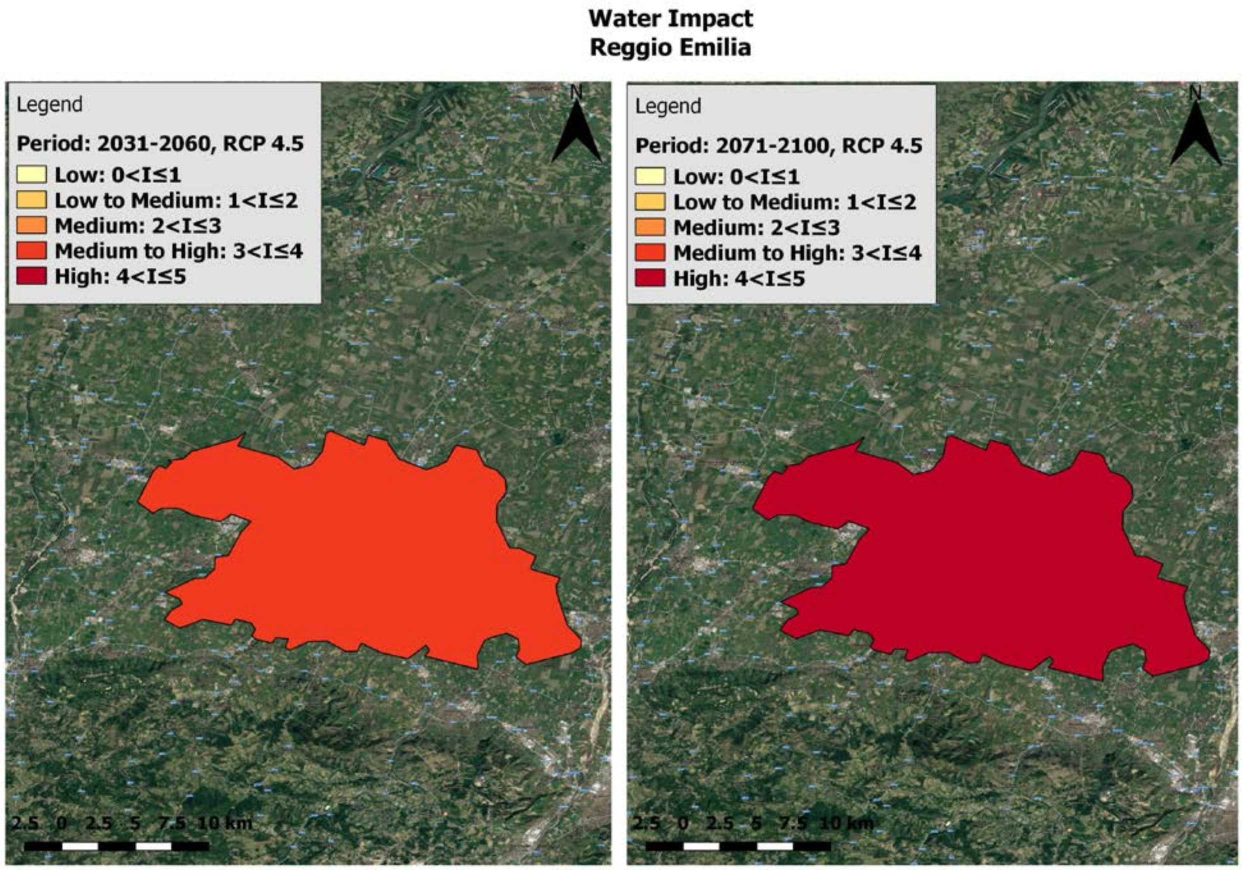

Figure 9: Water impact maps of Reggio Emilia municipality for scenario 4.5. Time period 2031-2060 (left) and time period 2071-2100 (right)

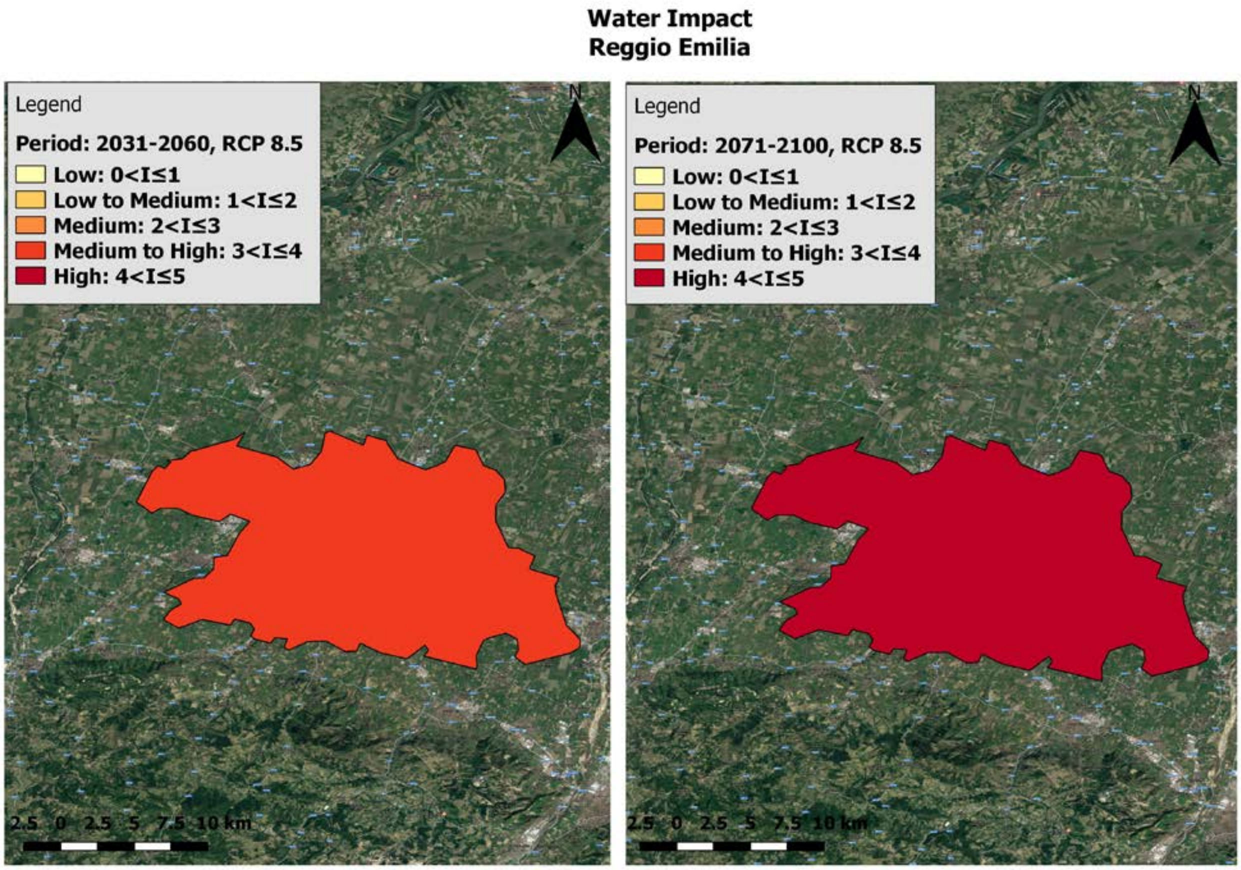

Figure 10: Water impact maps of Reggio Emilia municipality for scenario 8.5. Time period 2031-2060 (left) and time period 2071-2100 (right)

5. Flood impact assessment

For the assessment of flood impact in the project municipalities, a number of hazard, exposure and social vulnerability indicators were used according to Equations 1 and 2.

With respect to the hazard indicators which are related to the climatic information, an investigation of the trends in relevant climatic indicators took place, such as the projected maximum precipitation within one day and five days, as well as, the projected number of heavy and very heavy precipitation days. However, the investigation revealed no statistical significant trends during the examined future periods in all municipalities under both future emission scenarios, RCP4.5 and RCP8.5. Therefore, it was decided to alternatively assess flood hazard.

In particular, flood hazard maps produced by the competent national authorities in compliance with the Floods Directive 2007/60/EC were used for identifying the location and extent of the area potentially affected by flooding (flood hazard zone) in each municipality. The precipitation levels taken into account for the construction of the flood hazard maps for the different flood return periods were correlated to the projected precipitation levels provided by the National Observatory of Athens in the frame of this project, in order to select those flood hazard maps referring to the flood return period which is closer to the projected precipitation levels. The correlation showed that precipitation levels of the 100-year flood return periods are closer to the projected ones in all areas under examination, and therefore the respective maps were used. All areas within the flood hazard zone were assigned a value of “3”, which correspond to a medium level hazard according to the rating scale used in the current study (see Table 1).

The hazard indicator is enhanced with an extra weight where low-lying areas (inclination: $<1^o$) are located next to rivers. In particular, hazard is multiplied with the normalized value of the percentage coverage of low-lying areas in each land use polygon. The normalization is made based on the classification scale presented in Table 25. The information on low-lying areas is provided for each project municipality through Action C1.2 of the project (for more information see Deliverable C1.2).

Table 25: Normalization of low-lying area coverage values

Initial classes		Normalized classes	
From	**To**	**From**	**To**
0.0%	20.0%	1.0	1.15
20.0%	40.0%	1.15	1.30
40.0%	60.0%	1.30	1.45

60.0%	80.0%	1.45	1.60
80.0%	100.0%	1.60	1.75

Exposure to floods takes into account both population and critical infrastructure within the flood hazard zone. In particular for the former, the quantity and spatial distribution of population expressed as population density was used. This indicator serves thus as proxy for expected number of residents exposed to the risk of flooding. The information on population is available at the level of building blocks and land use polygons in general through the Urban Atlas database of the Copernicus Land Monitoring Service. Next, the population data were processed with the use of GIS software in order to calculate population density for each polygon (inhabitants per Km2). Due to the high fluctuation of population density among the project municipalities and for simplicity purposes, the decimal logarithm of all population densities of each land use polygon of each municipality, was used. For the classification, the range was divided into 5 equal classes with scores ranging from 0 to 5, from very low population density to very high, as shown in Table 26.

Table 26: Normalization of population density values (Log10 inh/km2)

Initial classes		Normalized classes	
From	**To**	**From**	**To**
0.0	0.1	0	1
0.1	2.2	1	2
2.2	3.4	2	3
3.4	4.5	3	4
4.5	5.6	4	5

The exposure is also estimated with respect to the critical infrastructure exposed to floods, such as hospitals, schools, commercial and industrial areas, public facilities, cultural units and transport infrastructure. The flood zone areas where critical infrastructure is located may indicate at the same time the exposure of population and of the critical infrastructure to floods. A failure of critical infrastructure means a substantial disturbance of public life and undermine the security of service supply. The scores assigned to the land use polygons where critical infrastructure is located are based on the scores proposed by the Special Secretariat for Water (2017) for the flood vulnerability and risk assessment methodology. In particular, the proposed classification was in a slightly different 5-degree rating scale and it was adjusted so as to fit the scale used in the current study (Table 1). The final scores used are presented in Table 27.

Table 27: Critical infrastructure category values

Category	Values
Education units	2.5
Health units	3.5
Cultural units	0.5
Industrial, commercial areas and public facilities	2.5
Other roads and associated land	2.0
Railways and associated land	2.5
Fast transit roads and associated land	2.5

The social vulnerability indicators that were taken into account in the flood impact assessment are the age, the illiteracy, the low-income, the chronic diseases and the number of hospital beds (for more information see section 3). The impact assessment formula, as this is formed for the case of floods is presented next:

$$\boldsymbol{I_{floods} = bH * (P + I) * aVs} \qquad \textit{(Eq. 16)}$$

Where, $\boldsymbol{I_{Floods}}$ the flood impact, ***H*** the flood hazard zone (value set to 3), ***b*** the weight of the hazard indicator for the low-lying areas, ***P*** the population exposure, ***I*** the exposure of critical infrastructure, ***Vs*** the composite social vulnerability index for floods and ***a*** the weight applied to the social vulnerability to denote its contribution to the overall impact assessment (value set to 0.4).

As one may observe, the equation above does not take into account the retainment of run-off and the increase of infiltration capacity where areas with green space (vegetation, trees etc.) are maintained. The effect of green space in reducing the flood impact is estimated with the use of Equation 3, where adaptation is quantified by means of runoff coefficients. In particular, while a built residential or commercial/industrial area is characterized by a runoff coefficient of 0.7 on average, a green area within a municipality (e.g. a sparsely vegetated area or a forest area with <50% of the land covered) has a runoff coefficient of 0.33-0.44 (Zimmermann et al., 2016). Therefore, it may be suggested that the green areas reduce the impact of floods in approximately half of the initially estimated impact. Geospatial information on the green areas provided for all the project municipalities in the frame of Action C1.2 is exploited in the current study to assess the green area coverage in each land use polygon and the adaptation effect. In the table that follows the respective rating scale for adaptation is presented.

Table 28: Normalization of the adaptation indicator on green area coverage

Initial classes		Normalized classes	
From	**To**	**From**	**To**
0%	20%	0	0.5
20%	40%	0.5	1.0
40%	60%	1.0	1.5
60%	80%	1.5	2.0
80%	100%	2.0	2.5

The proposed rating scale will be tested, calibrated and further defined with field measurements, during the monitoring of the performance of the green infrastructure measures that will be implemented in the project municipalities during Action C.7 of the project.

The flood impact assessment results are presented in the table that follows as well as in the following maps. As it may be seen, the municipality of Peristeri is expected to face the most significant flood impacts with the flood zone covering 29% of its total area, and an overall impact score of the flood zone area classified as “high” (4.6), which is translated to a “medium to high” overall impact score for the municipality (3.7). Next is the municipality of Strovolos and Lakatamia with a “medium” overall flood impact score for the municipality (2.4 and 2 respectively) and the municipality of Reggio Emilia with a “low to medium” overall flood impact score for the municipality (1.5).

Impact class	Peristeri	Strovolos	Lakatamia	Reggio Emilia
Low (0-1)	1.2%	4.3%	4.5%	36.9%
Low to medium (1-2)	1.5%	0.2%	5.4%	8.1%
Medium (2-3)	7.9%	36.7%	53.9%	46.3%
Medium to high (3-4)	18.6%	12.6%	8.5%	6.5%
High (4-5)	70.8%	46.1%	27.8%	2.2%

Impact class	Peristeri	Strovolos	Lakatamia	Reggio Emilia
Overall impact score of the flood zone area [A]	**4.6**	**4.0**	**3.5**	**2.3**
Share of the flood zone area to the municipality area (%)	28.9%	8.1%	5.9%	7.8%
Share of the flood zone area to the municipality area (norm) [B]	**2.9**	**0.8**	**0.6**	**0.8**
Overall flood impact score of the municipality [C]=[A*B] $^{1/2}$	**3.7**	**2.4**	**2.0**	**1.5**

The percentage values depicting the share of the flood zone area to the municipality area have been normalized based on Table 28.

Table 29: Normalization of the % share of the flood zone area to the municipality area

Initial classes		Normalized classes	
From	**To**	**From**	**To**
0%	10%	0	1
10%	20%	1	2
20%	30%	2	3
30%	40%	3	4
40%	100%	4	5

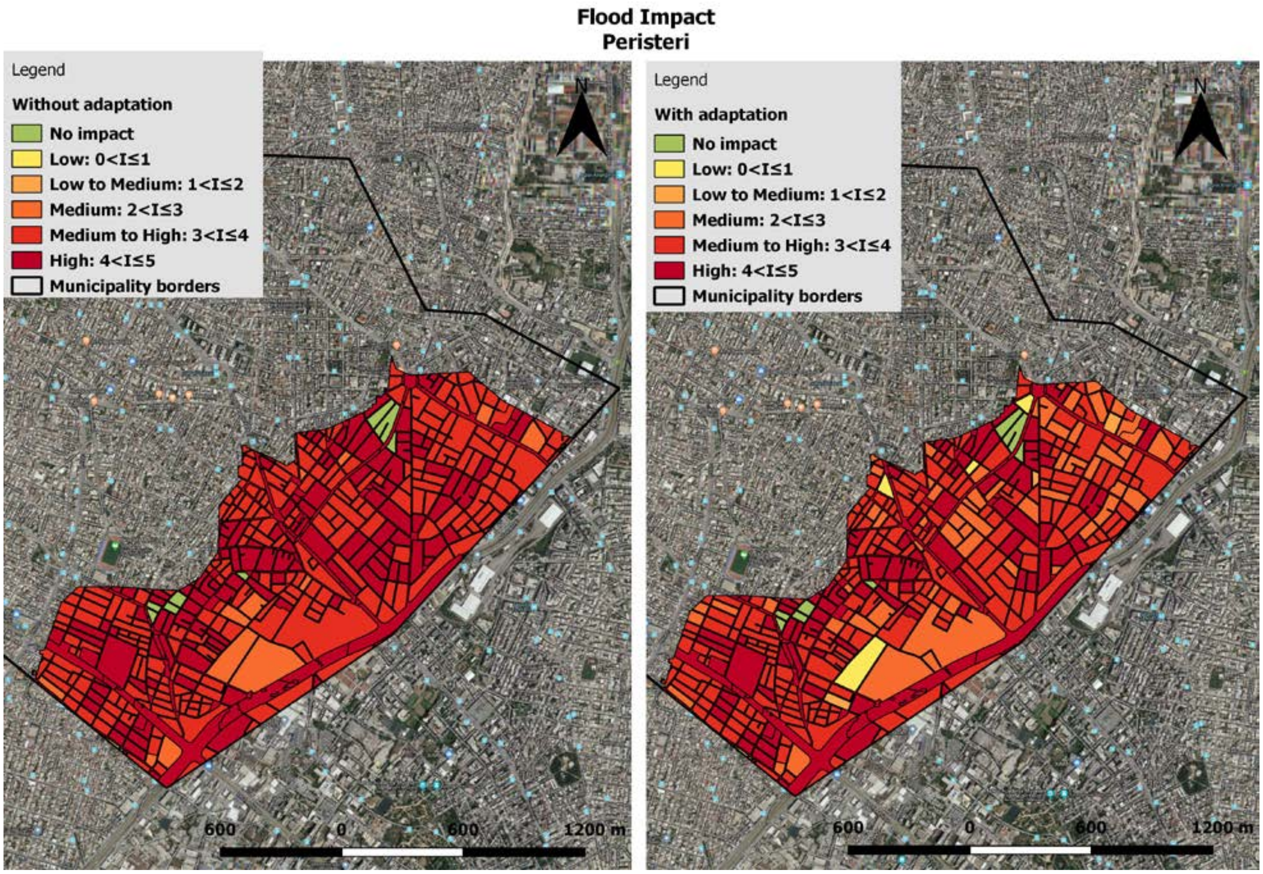

Figure 11: Flood impact maps – Peristeri municipality

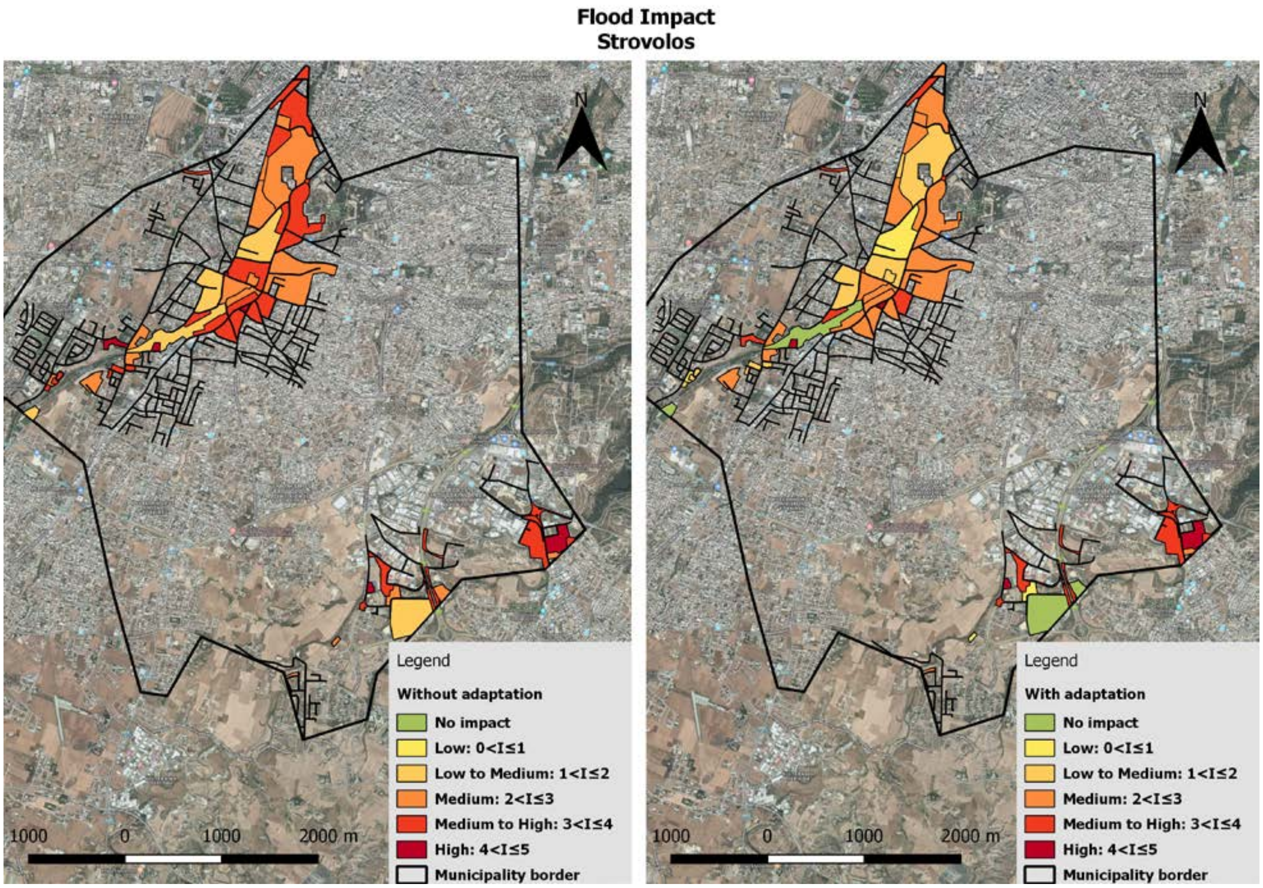

Figure 12: Flood impact maps – Strovolos municipalities

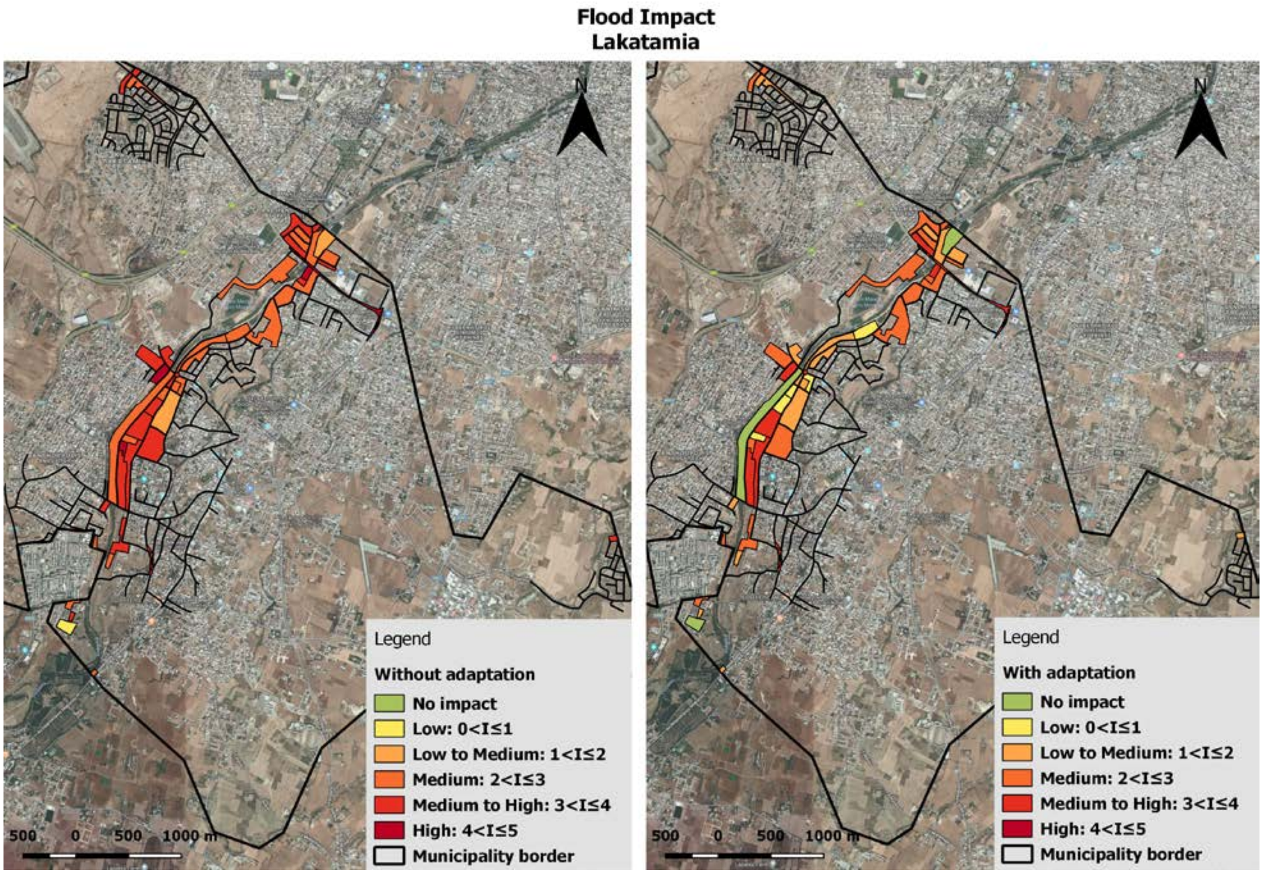

Figure 13: Flood impact maps –Lakatamia municipality

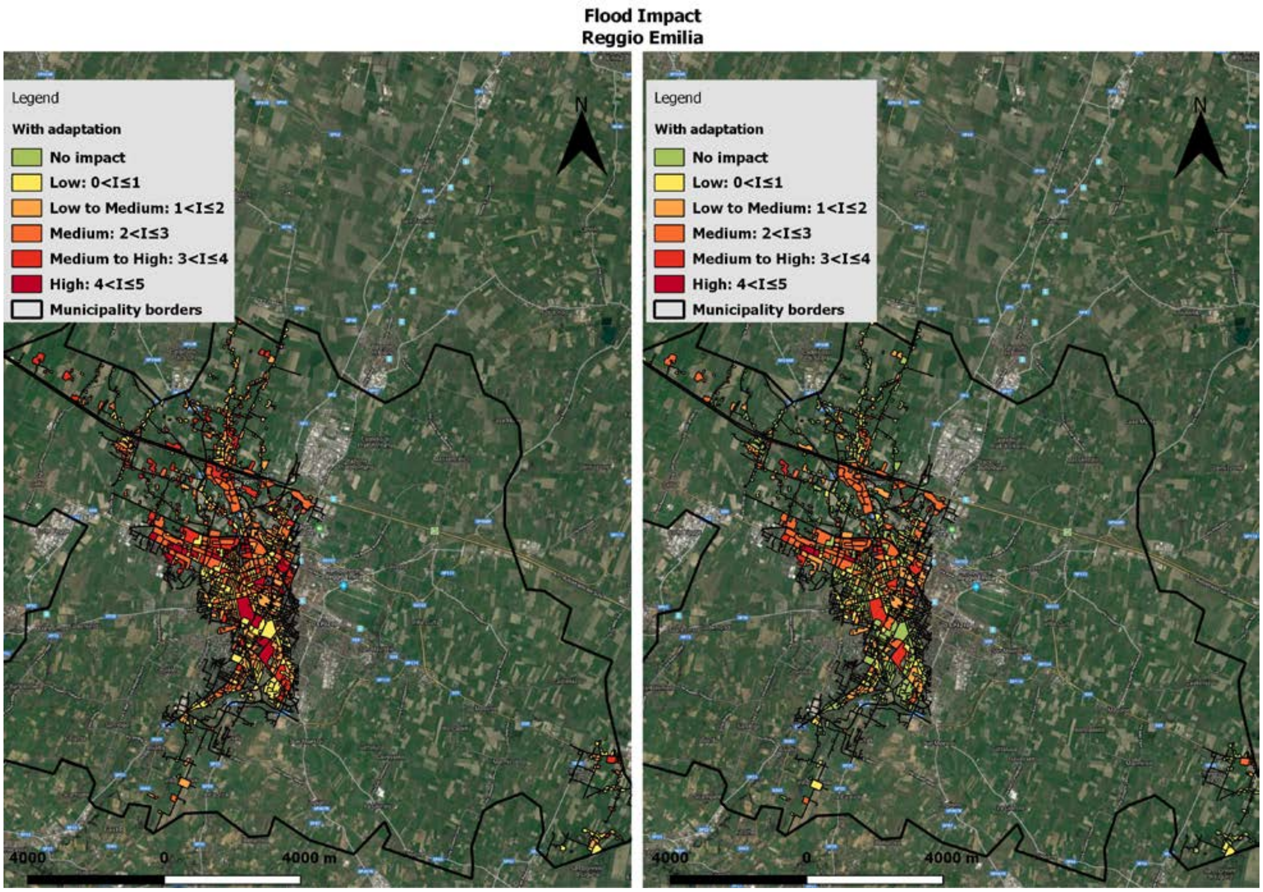

Figure 14: Flood impact maps – Reggio Emilia municipality

6. Adaptation assessment

For the adaptation assessment, a review of the available adaptation measures for addressing water availability and flood climate change impacts took place. Following, a questionnaire was developed for the evaluation of the adaptation measures based on a set of criteria (Multi-Criteria Analysis, MCA). Potential adaptation measures evaluation was based on four criteria related to efficiency, environmental friendliness, economic viability and job growth. The measures were evaluated against these criteria by a number of experts & stakeholders (national, regional, local authorities; neighbouring municipalities and Unions; NGOs & CSOs; companies; academic bodies & research institutes) from Italy, Greece and Cyprus. The evaluation scores are presented in the tables that follow, with the total score corresponding to the average value of the scores attained to the four criteria. The total score was used for the prioritization of the adaptation measures in their inclusion to the adaptation strategies of the project municipalities.

Furthermore, the effect of the adaptation measures in moderating the impacts of water availability and floods (impact after adaptation) is presented in the last column of the tables, where the score attained under the criteria “Efficiency in addressing the impact” was subtracted from the maximum impact score of “5”, according to Equation 3.

Table 30: Evaluation results of water availability adaptation measures

Adaptation measures	**Criteria**					**Impact after implementa-tion of the measure**
	Efficiency in addres-sing the impact	Environ-mental Friend-liness	Economic Viability	Job growth	**Total score**	
Water saving appliances for buildings	4.1	4.3	2.4	2.7	**3.4**	**0.9**
Rain gardens	3.1	4.1	2.7	2.3	**3.1**	**1.9**
Greywater re-use (domestic)	3.4	3.9	3.1	1.6	**3.0**	**1.6**
Lake restoration	3.4	4.2	1.3	3.1	**3.0**	**1.6**
Water metering systems	3.3	4.0	2.6	1.9	**2.9**	**1.7**
Infiltration / Detention basins	3.3	3.7	2.5	2.1	**2.9**	**1.7**
Rehabilitation of water distribution network	3.3	3.5	2.5	2.5	**2.9**	**1.7**
Rainwater harvesting at buildings	3.0	3.9	2.8	1.7	**2.8**	**2.0**
Wastewater treatment plants	3.5	3.4	1.7	2.7	**2.8**	**1.5**
Riverbed material restoration and re-naturalization	2.9	4.0	1.9	2.4	**2.8**	**2.1**

Adaptation measures	Criteria					Impact after implementation of the measure
	Efficiency in addressing the impact	Environmental Friendliness	Economic Viability	Job growth	**Total score**	
Permeable paving	2.8	3.6	2.6	2.1	**2.8**	**2.2**
Infiltration trenches and Swales	3.1	3.6	2.2	2.2	**2.8**	**1.9**
Artificial groundwater recharge through wells	2.8	3.3	2.9	1.7	**2.7**	**2.2**
Soakaways	3.1	3.3	2.2	2.1	**2.7**	**1.9**
Desalination	3.6	2.4	1.9	2.7	**2.7**	**1.4**
Water restrictions	2.7	3.6	3.8	0.5	**2.6**	**2.3**
Re-meandering	2.8	3.4	1.1	2.8	**2.5**	**2.2**
Dikes and dams re-enforcing	2.6	2.1	1.5	2.5	**2.2**	**2.4**

Table 31: Evaluation results of flood adaptation measures

Adaptation measures	Criteria					
	Efficiency in addressing the impact	Environmental Friendliness	Economic Viability	Job growth	**Total score**	**Impact after implementation of the measure**
Trees in urban areas	3.3	4.6	3.3	2.0	**3.3**	**1.7**
Retention ponds	4.1	3.6	1.8	2.8	**3.1**	**0.9**
Forest riparian buffers	3.3	4.5	2.3	2.0	**3.1**	**1.7**
Riverbed material restoration and re-naturalization	3.8	3.9	1.5	2.9	**3.0**	**1.2**
Lake restoration	3.8	4.2	1.1	2.8	**2.9**	**1.2**
Channels and rills	3.4	3.6	1.8	3.0	**2.9**	**1.6**
Filter strips	3.2	3.8	2.3	2.4	**2.9**	**1.8**
Green Roofs	3.1	4.0	1.6	2.9	**2.9**	**1.9**
Permeable paving	3.4	3.3	2.2	2.6	**2.9**	**1.6**
Infiltration trenches and Swales	3.7	3.3	2.3	2.2	**2.9**	**1.3**
Rain gardens	3.3	3.6	2.5	2.1	**2.8**	**1.7**
Infiltration / Detention basins	3.8	3.2	1.8	2.3	**2.8**	**1.2**

Adaptation measures	**Criteria**					
	Efficiency in addres-sing the impact	Environ-mental Friend-liness	Economic Viability	Job growth	**Total score**	**Impact after implementa-tion of the measure**
Sediment capture ponds	3.5	3.2	2.3	2.0	**2.7**	**1.5**
Re-meandering	3.5	3.3	1.4	2.6	**2.7**	**1.5**
Soakaways	3.1	2.6	1.6	2.5	**2.5**	**1.9**
Dikes and dams re-enforcing	2.6	1.8	0.7	2.7	**2.0**	**2.4**

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Supplementary information on adaptation measures for addressing climate change impacts

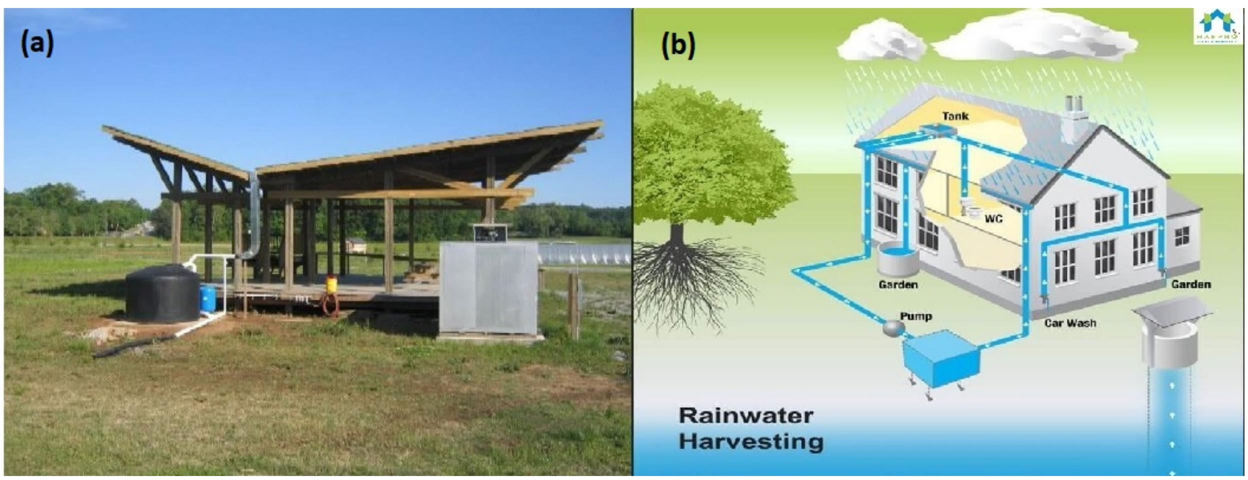
Contents

Supplementary information on adaptation measures for addressing climate change impacts

1 Adaptation Measures for addressing climate change impacts on water availability

1.1 Rainwater Harvesting at buildings

Rainwater harvesting involves collecting and storing rainwater at source for subsequent use, for example, using water butts or larger storage tanks. It's a simple rainwater harvesting technique, collecting rainwater runoff from roofs via a connection to the roof down-pipe.



Source: (a)http://www.happho.com/rainwater-harvesting-rwh-system-individual-houses-india/

(b) http://www.clemson.edu/sustainableag/rainwater.html

<u>Impacts</u>:

- **Store Runoff → None to Low** *(Rainwater harvesting stores runoff for local use, with the potential therefore to reduce both the rate and total volume of runoff. However the actual effectiveness of rainwater harvesting is highly dependent on whether the system is specifically designed for runoff storage or whether the primary aim is water storage.)*
- **Slow Runoff → None to Low**

- **Water Storage → High** *(Rainwater harvesting captures rainwater at source, which is then stored to be used for irrigation or other non-potable purposes.)*

Capital and maintenance costs:

- Capex → 5-60 €/m^2 roof area
- Maintenance → 0.25-1.00 €/m^2 roof area services.

1.2 Artificial Groundwater Recharge through Wells

Groundwater is the part of infiltrated water which composes the water resource for population and human activities. Restoration of natural infiltration to groundwater enables a lowering of run-off from surrounding land, and enhances the condition of groundwater aquifers and water availability. The natural cleaning processes associated with infiltration can improve water quality. This measure can also be known as "Artificial Groundwater Recharge" in the engineering literature.

One of the mechanisms to restore or enhance natural infiltration capacity is through wells and include:

- subsurface indirect recharge – infiltration capacity is enhanced through wells drilled within the unsaturated zone
- subsurface direct recharge – infiltration and recharge of the groundwater aquifer is accomplished through wells reaching the saturated zone

Impacts:

- **Store Runoff → Low** *(This measure, by enhancing infiltration into deep soil, especially with shallow wells, can increase its capacity for storing runoff)*
- **Slow Runoff → Medium** *(Rain falling on the landscape may flow quickly over soil or rock surfaces as runoff to stream channels. Alternately, some water may flow more slowly downslope toward streams within the soil. Some may percolate downward through pores in soil and fractures in rock to reach the top of the saturated zone (often called the water table). Below the saturated zone, it flows much more slowly as groundwater. Therefore increasing*

recharge to groundwater reduces the amount of water available for rapid surface runoff and increases availability of groundwater for baseflow.)

- **Increase infiltration and/or groundwater recharge → High** *(Restoration of natural infiltration to groundwater enables groundwater recharge. The significance of the latter depends on the number of structures restored.)*
- **Increase soil water retention → Low** *(Soil water retention might slightly change according to the infiltrated water.)*
- **Reduce erosion and/or sediment delivery → Low** *(Depending on their surface areas, infiltration basins may intercept sediment.)*

Capital and maintenance costs:

- Capex → n/a
- Maintenance → n/a

1.3 Desalination

Desalination is the process of removing salt from sea or brackish water to make it useable for a range of purposes including drinking. It may thus contribute to adaptation to climate change in all those circumstances in which water scarcity problems may be exacerbated in the future. Desalination produces a by-product, brine (a concentrated salt solution) that must be disposed. Desalination techniques include:

- Electrically driven technologies: Reverse osmosis is the most frequently used technique: it consists of filtering water with osmosis membranes that separate salt from water. Other techniques include Mechanical Vapour Compression (MVC) and Electrical Dialysis (EDR)
- Thermally driven technologies: Multistage flash distillation (MSF), multi effect distillation (MED), Thermal Vapour Compression (TVC) and Membrane Distillation (MD).

Source: https://www.exportersindia.com/shield-management-consaultancy/water-desalination-plant-2779378.htm

Costs:

Investment and operation costs are still very high, which makes desalination not suited for large water consuming sectors. Energy consumption can account for half of the desalination cost, which makes energy savings a very important element to cut the costs of desalination. Desalination is very sensitive to electricity prices. In general costs have decreased significantly because of technology improvement but are depending on plant size, raw water quality, energy costs and terms of financing.

1.4 Water Recycling

1.4.1 Large scale: Wastewater treatment plants

Recycling of water is considered as an adaptation measure to save resources through reuse for not-for-drinking uses. Wastewater reuse can therefore be a valuable option for water supply in areas where water is limited. Two types of reuse exist: direct and indirect. Direct reuse is treated wastewater that is piped into a water supply system without first being diluted in a natural stream/lake or groundwater. Indirect reuse involves mixing of reclaimed wastewater with another water supply before re-use. Both types are of interest as a grey climate change adaptation options.

Treated wastewater can serve as a more dependable water source, contributing to a more sustainable resource utilization and sound demand management. The measure can reduce overall water consumption and treatment needs, resulting in cost savings. Looking at the environment, the reuse of treated water allows for the conservation and allocation of freshwater and can enhance the restoration of streams, wetlands and ponds.

Source: http://www.ss-fab.com/formaldehyde-plant.html

Costs:

The possible benefits of the reuse of treated water are various, including economic, social and environmental benefits. These benefits include reducing household water demand and ease pressure on the main water supply, reducing upstream energy and environmental costs. The cost of recycled water may exceed that of fresh water but it is justified by the series of benefits water recycling provides: it saves high quality water for drinking, it reduces the amount of polluted water released to the environment, it may have a quality making it suitable for specific uses. Recycled water prices may consider all those side effects and justify cheaper rates through public subsidies to encourage its use.

Capital costs is depending on treatment processes and plant capacity. Construction cost is calculated between 261000 and 336000 $ (is about the same amount in €) for an average wastewater flow about 4000 gpd (gallons per day) and 874000 $ - 1092000 $ for a plant with average capacity of 100000 gpd.

Maintenance & operational costs is about 20000 to 52500 $/year for a plant with total capacity of 4000 gpd and 78000 to 132000 $/year for a plant with total capacity 100000 gpd (Hartman & Cleland, 2007).

1.4.2 Small scale: Greywater re-use

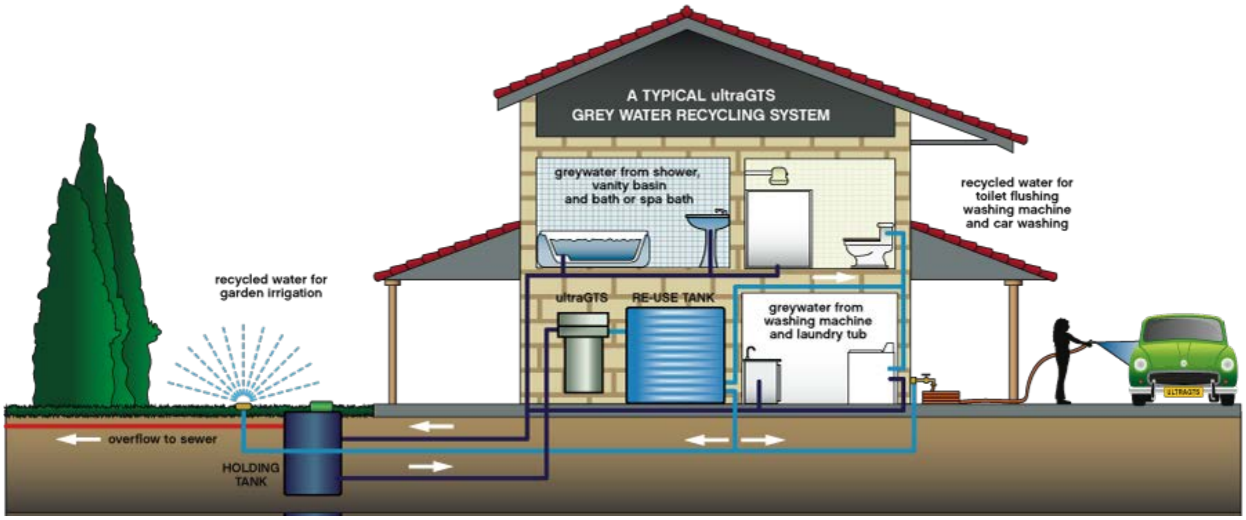
Greywater is wastewater from showers, baths, washbasins, washing machines and kitchen sinks. The water can be collected from some or all of these sources and, after treatment, use around the home for purposes that do not require drinking water quality such as toilet flushing or garden watering. It can operate at a single property scale or on a development-wide scale (Environment agency, 2015).

If used for toilet flushing, a well-designed and fully functional greywater system could potentially save a third of the mains water used in the home. Greywater can also be used for other purposes where potable water quality is not essential, such as garden watering. The greater the proportion of greywater used, the less mains water will be needed, which will ease the pressure on water resources (Environment agency, 2011).

Greywater reuse systems vary significantly in their complexity and size from small systems with very simple treatment to large systems with complex treatment processes. However, most have common features such as:

- a tank for storing the treated water
- a pump
- a distribution system for transporting the treated water to where it is needed and
- some sort of treatment.

All systems that store greywater have to incorporate some level of treatment, as untreated greywater deteriorates rapidly in storage.



Source: https://greywaterau.wordpress.com/

Costs: approximately 3375 € per property (EA, 2007).

1.5 Rehabilitation of water distribution network

Upgrading or improvement of a water distribution network is often costly and usually involves the options of:

- adding new infrastructure (pipes, pumps, etc.)
- replacement of old infrastructure or
- a combination of these.

However, network rehabilitation deals with a large class of problem pertaining to network ageing and performance deterioration, which includes renewal, bursts, leakage, poor water quality, reliability, increase in demand and pressure requirements. The process of network upgrading usually involves the engineer in predetermining the design constraints for the new water distribution network. For example, the assumption of certain demand patterns (usually an increase in demand) or certain locations having some minimum pressure head requirements has to be met (Thiam Khu & Keedwell, 2011).

1.6 Water restrictions

Water restriction limit certain uses of water for example irrigation of lawns, car washing, filling swimming pools, or hosing down pavement areas. Restrictions can limit the availability of water in terms of volume and/or the time when it can be used and its purpose. Water rationing include usually temporary suspension of water supply, or reduction of pressure below that required for adequate supply under normal conditions. Rationing is associated with equitable distribution of critically limited water supplies in a way that ensure sufficient water is delivered to preserve public health and safety. Water restrictions and, to a lesser extent, rationing are frequently used especially in situations of temporary water scarcity (e.g. due to drought episodes). Both rationing and restriction that may be of temporal or permanent character, they allow local or even regional or national administration to cope with water crises, by reducing consumptions without substantial changes in the demand and supply ratio. Whenever those temporary low-cost coping measures are removed, water demand and use are expected to raise again return to previous levels. In case of persistent or recurrent scarcity other measures should be preferred to be implemented and maintained in the long-term: water saving measures to reduce water demand and/or more traditional strategies to increase water supplies, such as rain water harvesting, grey-water recycling and desalination.

Costs and benefits:

Compulsory water restrictions can produce significant water savings in a short time, comparable only to significant price increases. Restrictions are usually favored over economic instruments (e.g. water pricing) in temporary situations with critically limited water supplies.

1.7 Water metering systems

Water metering is a measure that provides information about water consumption. This type of measure can contribute to the reduction of water consumption, the detection of leakages and frauds. An effective application of this measure would ensure the development of a fair enough water pricing policy. Consumers is then likely to become more engaged in monitoring water use, leading to more efficient water use and also more active involvement in the identification of leaks (Mudgal, et al., 2012).

Advantages:

- Raising consumer awareness
- Fair pricing based on actual consumption and efforts by consumers

Issues:

- Costs of implementing meters in areas where they are not used
- May include change in tariff scheme

According to the water balance framework the total volume of water leakages due to lack of monitoring, inaccurancies in metering and unauthorized consumption is representing a significant share in the total sytem input volume.

<table>
<tr><td rowspan="9">System Input Volume</td><td rowspan="4">Authorised Consumption</td><td rowspan="2">Billed Authorised Consumption</td><td>Billed Metered Consumption</td><td rowspan="2">Revenue Water</td></tr>
<tr><td>Billed Unmetered Consumption</td></tr>
<tr><td rowspan="2">Unbilled Authorised Consumption</td><td>Unbilled Metered Consumption</td><td rowspan="7">Non-Revenue Water</td></tr>
<tr><td>Unbilled Unmetered Consumption</td></tr>
<tr><td rowspan="5">Water Losses</td><td rowspan="2">Apparent Losses</td><td>Unauthorised Consumption</td></tr>
<tr><td>Customer Meter Inaccuracies</td></tr>
<tr><td rowspan="3">Real Losses</td><td>Leakage on Transmission & Distribution Mains</td></tr>
<tr><td>Leakage on Service Connections up to the point of Customer Meter</td></tr>
<tr><td>Leakage and Overflows at Storage Tanks</td></tr>
</table>

Source: (Mudgal, et al., 2012)

The application of water metering systems can be useful in the effort to deal with the leakages of the distribution network.

Costs: The price of an average meter device ranges from 35 to 350 €, depending on its properties in terms of maximum flow capacity and accuracy of output data. More than one devices are needed per household (a meter device for cold water and another one for the hot water) and the costs is likely to be borne by the owners of the building (Mudgal, et al., 2012).

1.8 Water saving appliances for buildings

Water consumption in building can be achieved through the replacement of conventional Water using Products (WuPs) with new and improved products. WuPs include products that use water to fulfil their intended basic function such as toilets, showers, taps, washing machines, dishwashers and air conditioning. The installation of advanced and water efficiency products could be effective in water savings.

The potential water savings in listed below (Mudgal, et al., 2012).

WuP	Water savings
Low flush toilets	Use of 3 to 4.5 L/flush instead of 6 to 12 L/flush
	Water saving of 30 to 170 L/property per day
Water – saving showerhead	Water saving of 25.2 L/property /day
	Water saing of 8% compared to total household water consumption
AAA rated dishwasher	Water saving of 5000 L/year
	Water saving of 0.2% compared to total household water consumption
AAA rated front-loading washing machine	Water saving of 90 L comp[ared to conventional top loaders, i.e. about 16000 L per family per year.
	Water saving from 0.9 % compared to total household water

Potential improvements of the WuPs, is listed below (Benito, et al., 2009):

WuP	**Potential for improvement** (Residential buildings/commercial buildings)
Toilets	Dual flush / low flush or flush control
Taps	Aerators / spray taps, sensors, timed turn-off taps
Shoerheads	Aerating, laminar showerheads
Baths	Reduced volume
Washing machines	Intelligent function (load detectors) / waste water recycling
Dishwashers	Intelligent function (load detectors) / improve overall energy efficiency

2 Adaptation Measures for addressing climate change impacts on flood risk

2.1 Green Roofs

Green roofs are multi-layered systems that cover the roof of a building with vegetation and/or green landscaping over a drainage layer. They can be applied on artificial surfaces.

Source: http://cookjenshel.com/green-roofs/#!prettyPhoto[Gallery]/12/

Green roofs can be distinguished in two types according to the vegetation features:

- **Extensive green roofs** *(known as: sedum roofs, eco-roofs or living roofs)*

Info: low growing, self-sustaining, low maintenance planting.
Vegetation normally consists of hardy, drought tolerant, succulents, herbs or grasses.

- **Intensive green roofs** *(known as: roof gardens)*

Info: greater load on the roof structure and require significant ongoing maintenance including irrigation, feeding and cutting.

Impacts:

- **Store Runoff → Medium** *(for frequent, less extreme rainfall events. For larger rainfall events with a return period greater than two years, there will be some overflow)* (CIRIA, 2007)
- **Slow Runoff → Medium** *(Quantification of the effectiveness of green roofs at attenuation and peak flow reduction varying from 5% up to 95% reduction in runoff compared to a hard roof surface* [Blanc et al (2012)]*)*
- **Increase evapotranspiration → High** *(Evapotranspiration is likely to be more significant where the substrate is thicker)*
- **Reduce peak temperature → Low to Medium** *(Green roofs may contribute to improvements to air quality, lower air temperatures and higher humidity levels. The deeper the substrate is, the more effective the green roofs are. Lower level green roofs (are more likely to have a positive influence on the heat island effect. Green roofs effects on temperature, both to outside air temperatures in urban areas, as well as the insulating effect inside the building.)*
- **Absorb and/or retain CO_2 → Low** *("Extensive green roofs, being low in biomass, have little potential to offset carbon emissions from cities…intensive roof gardens that support woody vegetation could make significant contributions as an urban carbon sink")* [Oberndorfer et al (2007)]

Capital and maintenance costs:

- Capex → 25-130 €/m^2 extensive green roof area & 130-300 €/m^2 area for intensive green roofs
- Maintenance → Up to 55 €/m^2 area of green roof for each maintenance event. For the extensive roofs, general maintenance is every 6-12 months.

2.2 Trees in urban areas

Trees in urban areas can have multiple benefits related to aesthetics, microclimate regulation and urban hydrology. They can also be important biodiversity refuges and can contribute to reducing particulate air pollution. Trees intercept precipitation, reducing the amount of rainfall which must be processed by sewers and other water transporting infrastructure. The area around urban trees may also have greater infiltration capacity than the impermeable surfaces often found in urban areas. Trees also transpire, which dries the soil and gives greater capacity for rainfall storage.

Supplementary information on adaptation measures for addressing climate change impacts

Source: http://www.accessfayetteville.org/government/parks_and_recreation/park_planning_and_urban_forestry/urban_forest.cfm

Impacts:

- **Store Runoff → Medium** *(Because the area around urban trees is often more permeable than areas further away, urban trees have a moderate potential to store runoff.)*
- **Slow Runoff → Medium** *(Individual trees will have a real but limited ability to slow runoff in urban areas.)*
- **Increase evapotranspiration → High** *(Increased evapotranspiration (ET) is one of the main effects of trees on the hydrologic cycle. Trees in urban areas will increase ET, which can be beneficial in wet or temperate areas as it will reduce the amount of runoff entering storm drains and can increase the water holding capacity of the soil by leaving it drier than it would be if trees were not present.)*
- **Increase infiltration and/or groundwater recharge → Medium** *(Trees in urban areas can have a moderate effect on infiltration and groundwater recharge.)*
- **Increase soil water retention → Medium** *(Under some circumstances, trees in urban areas can increase soil water retention by facilitating greater rates of infiltration and enhancing groundwater recharge.)*

- **Reduce erosion and/or sediment delivery → Low** *(Because of their small "footprint" or zone of environmental influence, trees in urban areas have a limited ability to control erosion or to improve soils.)*
- **Improve Soils → Low**
- **Reduce peak temperature → High** *(The measure can contribute to reductions in peak temperature at ground level. Because trees have a higher albedo than many urban surfaces, they reflect instead of absorbing heat. The evapotranspiration from trees also contributes to local cooling.)*
- **Absorb and/or retain CO_2 → High** *(They can be locally important for absorbing and retaining CO_2.)*

Capital and maintenance costs:

- Capex → The capital costs of trees will depend on the age at which they are planted, with older, larger trees being more expensive than younger, smaller trees.
- Maintenance → The costs of pruning and maintaining trees need to be considered when planning trees in urban areas as a natural water retention measure.

2.3 Channels and rills

Channels and rills are shallow open surface water channels incorporated in to the start of a SuDS (Sustainable urban Drainage System) train. They collect water, slow it down and provide storage for silt deposited from runoff. They can have a variety of cross sections to suit the urban landscape, and can include the use of planting to provide both enhanced visual appeal and water treatment.

They can also be used in between SuDS features as connectors. Planting in channels and rills can visually enhance the urban landscape and offer biodiversity.

Supplementary information on adaptation measures for addressing climate change impacts

Source: http://nwrm.eu/measure/channels-and-rills

<u>Impacts</u>:

- **Store Runoff → Low** *(Channels and rills provide a small amount of storage, and help to control the rate of runoff. Planting in channels and rills can help to slow the rate of runoff.)*
- **Slow Runoff → Low to Medium**
- **Increase evapotranspiration → None to Medium** *(The rate of evapotranspiration will depend on dimensions, residence time and type of vegetation. In case that channels and rills are designed only to convey water, with a very low residence time, evapotranspiration will not be significant.)*
- **Increase infiltration and/or groundwater recharge → None to Low** *(when channels and rills have permeable beds and the residence time is low, It is likely to little infiltration to be achieved)*
- **Reduce erosion → Low** *(they have little influence on erosion itself. They encourage the deposition of sediments, thereby reducing the transport of sediment further downstream.)*
- **Reduce peak temperature → None to Low** *(Depending on vegetation density and how widespread they are, they can contribute to creating cool islands in urban landscapes)*

- **Absorb and/or retain CO_2 → None to Low** *(If a vegetated channel is added where no vegetation would otherwise be present, this will result in a small localized increase in uptake of CO2.)*

This measure constitutes a link between other measures and it is not appropriate to assign costs.

2.4 Filter strips

Filter strips are uniformly graded, gently sloping, vegetated strips of land that provide opportunities for slow conveyance and infiltration. They are designed to accept runoff as overland sheet flow from upstream development and often lie between a hard-surfaced area and a receiving stream, surface water collection, treatment or disposal system.

Filter strips are generally planted with grass or other dense vegetation to treat the runoff through vegetative filtering, sedimentation, and infiltration. Filter strips are best suited to treating runoff from relatively small drainage areas such as roads and highways, roof downspouts, small car parks, and pervious surfaces. Filter strips are often integrated into the surrounding land use, for example public open space or road verges.

Supplementary information on adaptation measures for addressing climate change impacts

Source: http://www.susdrain.org/delivering-suds/using-suds/suds-components/filtration/filter-strips.html

Impacts:

- **Slow Runoff → Low** *(Due to their rough surface, filter strips can provide some slowing of runoff, but this may be relatively minor since there is no storage capacity as such.)*
- **Increase evapotranspiration → Low** *(The rate of evapotranspiration will depend on dimensions, residence time and type of vegetation. With dense vegetation and relatively low velocities, evapotranspiration is substantially increased, particularly if trees are planted.)*
- **Increase infiltration and/or groundwater recharge → Low** *(The infiltration is little due to the low residence time)*
- **Increase soil water retention → Low** *(Introduction of vegetation may over time increase the organic matter content and associated ability of the soil to retain water.)*
- **Reduce erosion and/or sediment delivery → High** *(Sediment deposition is the primary aim of filter strips, achieved by capture of sediment in vegetation at low flow velocities.*
- **Reduce peak temperature → Low** *(Filter strips provide green areas. Depending on vegetation density and how widespread they are, they can contribute to creating cool islands in urban landscapes as a result of evapotranspiration, water supply, shading.)*
- **Absorb and/or retain CO_2 → Low** *(If a filter strip is added where no vegetation would otherwise be present, this will result in a localized increase in uptake of CO_2, particularly if woody vegetation is included.)*

Capital and maintenance costs:

- Capex → 3-30€/m² filter strip area
- Maintenance → 0.5-6.5€/m² filter strip area

2.5 Retention Ponds

Retention ponds are ponds or pools designed with additional storage capacity to attenuate surface runoff during rainfall events. They consist of a permanent pond area with landscaped banks and surroundings to provide additional storage capacity during rainfall events. They are created by using an existing natural depression, by excavating a new depression, or by constructing embankments.

Retention ponds can provide both storm water attenuation and water quality treatment by providing additional storage capacity to retain runoff and release this at a controlled rate. Ponds can be designed to control runoff from all storms by storing surface drainage and releasing it slowly once the risk of flooding has passed. They have good capacity to remove urban pollutants and improve the quality of surface runoff.

Well-designed and maintained ponds can offer aesthetic, amenity and ecological benefits to the urban landscape, particularly as part of public open spaces. They are designed to support emergent and submerged aquatic vegetation along their shoreline. They can be effectively incorporated into parks through good landscape design.

Source: http://nwrm.eu/measure/retention-ponds

Impacts:

- **Store Runoff → High**
- **Slow Runoff → High** *(Retention ponds reduce peak runoff through storage and controlled outflow release. They must be appropriately sized to the catchment area and critical storm depth. They do not infiltrate runoff and therefore provide very little runoff volume reduction Typically, retention ponds will be designed to attenuate runoff for events up to at least the 1 in 30 year storm for the drainage area (CIRIA, 2007))*
- **Increase evapotranspiration → Medium** *(The rate of evapotranspiration will depend on dimensions, residence time and type of vegetation. With dense vegetation, evapotranspiration is substantially increased, particularly if trees are planted.)*
- **Reduce erosion and/or sediment delivery → High** *(Retention ponds are highly effective at intercepting sediment loading in runoff. When designed with a sediment trap that can be easily cleared, effectiveness at sediment removal is compatible with the long-term effectiveness of the pond to attenuate runoff.)*
- **Reduce peak temperature → Low to Medium** *(They provide green areas and open water. Depending on vegetation density and how widespread they are, they can contribute to creating cool islands in urban landscapes)*
- **Absorb and/or retain CO_2 → Low to Medium** *(If a retention pond is added where no vegetation would otherwise have been present, this will result in a localized increase in uptake of CO_2, particularly if woody vegetation is included.)*

Capital and maintenance costs:

- Capex → 10-60€/m^3 storage volume
- Maintenance → 1-5€/m^2 pond surface area

2.6 Forest riparian buffers

Riparian buffers are treed areas alongside streams and other water bodies. Riparian buffers can be found in urban, agricultural and wetland areas. By preserving a relatively undisturbed area adjacent to open water, riparian buffers can serve a number of functions related to water quality and flow moderation. The trees in riparian areas can efficiently take up excess nutrients and may also serve to increase infiltration. Riparian buffers serve to slow water as it moves off the land. This can decrease sediment inputs to surface waters.

Source: http://en.wikipedia.org/wiki/Riparian_buffer

Impacts:

- **Store Runoff → Medium** *(Because of their relatively small coverage of the total landscape, riparian forest buffers have a limited ability to store terrestrial runoff.)*
- **Slow Runoff → Medium** *(Forest riparian buffers have limited ability to slow runoff, primarily due to their relatively small breadth.)*
- **Slow River Water → Low** *(Deadwood from forested banks may decrease stream velocity. During overbank flooding also riparian vegetation may potentially slow the flows.)*

- **Increase evapotranspiration → Low** *(Forest riparian buffers can cause a slight increase in evapotranspiration (ET) if the trees in the buffer have greater rates of ET than the surrounding area.)*
- **Increase infiltration and/or groundwater recharge → Low** *(Forests are well known for their ability to increase infiltration and/or groundwater recharge. Forest riparian buffers have only a low effect on infiltration, groundwater recharge and soil water retention. This low effect is primarily due to their relatively small coverage of a whole catchment.)*
- **Increase soil water retention → Low**
- **Reduce erosion and/or sediment delivery → High** *(One of the primary design purposes of riparian forest buffers is to reduce sediment delivery to streams following clearcut. Riparian buffers have little or no effect on erosion within the catchment but can retain much of the eroded sediment, preventing it from reaching streams.)*
- **Improve Soils → Low** *(Under some circumstances, forest riparian buffers can have a beneficial effect on riparian soils by promoting greater infiltration, soil porosity and organic carbon accumulation. However, these improvements will be limited to the buffer zone area.)*
- **Reduce peak temperature → Medium** *(Relative to an open site, forest buffer tends to decrease solar radiation and wind speed and moderate diurnal air temperature variations.)*
- **Absorb and/or retain CO_2 → Low** *(When forest biomass in the riparian zone exceeds the biomass that had been present earlier, forest riparian buffers can play a limited role in retaining CO_2.)*

Capital and maintenance costs:

- Capex → There are typically no capital costs as no land is already owned.
- Maintenance → There are typically no maintenance costs for forest riparian buffers.

2.7 Sediment capture ponds

Sediment capture ponds are engineered ponds placed in networks of forest ditches to slow the velocity of water and cause the deposition of suspended materials. They are most useful for managing the effects of ditch construction and maintenance, road work and final feeling. While used primarily in forests, sediment capture ponds may be a useful temporary measure for preserving water quality in and around construction sites or mines. They may also be useful for capturing sediment in agricultural runoff. Sediment capture ponds have a limited lifespan, depending on how much suspended material is in the inflowing water. However, they can be maintained by removal of accumulated sediment. As most water protection methods, sediment capture ponds function well during base and moderate flow events. Catchment area, hydraulic properties of ditches, discharge rate and soil characteristics are among factors influencing functioning of sedimentation capture ponds.

Source: http://nwrm.eu/measure/sediment-capture-ponds

Impacts:

- **Store Runoff → Medium** *(Because of their small size, sediment capture ponds have a limited ability to store runoff. However, a network of sediment capture ponds distributed across the landscape may have a significant ability to store runoff, especially during dry conditions when the ponds are empty and have an ability to retain added precipitation.)*
- **Slow Runoff → Medium** *(The sediment capturing ability of ponds is based on a slowing of water velocity. Thus, this measure will have a localized ability to slow runoff. Multiple ponds distributed across the forest landscape might have a significant ability to slow runoff during drier periods.)*
- **Store River Water → Low** *(It is questionable whether or not it is appropriate to state that sediment capture ponds store or slow river water as their use is limited to ditch networks and*

potentially headwater streams. However, within these smaller watercourses, sediment capture ponds will both store and slow water.)

- **Slow River Water → Low**
- **Increase infiltration and/or groundwater recharge → Low** *(Because sediment capture ponds will store and slow water, they have some limited potential to increase infiltration and groundwater recharge.)*
- **Increase soil water retention → Low** *(Increased infiltration because of slower water flows can also have some benefits for soil water retention.)*
- **Reduce erosion and/or sediment delivery → High** *(The key purpose of sediment capture ponds is to reduce the delivery of sediment from managed forests to receiving waterbodies.)*
- **Absorb and/or retain CO_2 → Negative** *(There is a possibility for increased greenhouse gas emissions from sediment capture ponds associated with the breakdown of organic sediments. Sediment capture ponds may release CO_2, methane, and potentially N_2O.)*

Capital and maintenance costs:

- Capex → Low *(There will be slightly higher costs associated with creation of ditch networks when sediment capture ponds are present as the volume of material excavated will be slightly larger than it would be if no ponds were created.)*
- Maintenance → Low *(There are maintenance costs associated with dredging of sediment capture ponds. The frequency of dredging will depend on the sediment load in the ditches.)*

3 Adaptation Measures for addressing climate change impacts both on water availability and flood risk

3.1 Permeable Paving

Permeable paving is designed to allow rainwater to infiltrate through the surface, either into underlying layers (soils and aquifers), or be stored below ground and released at a controlled rate to surface water.

Source: (b) http://www.sure-ground.com/products/truckgrid-max-permeable-grids

(a) https://www.pacificpavingstone.com/blog/favorite-permeable-paving-manufacturers-landscapes-streetscapes/

Two types of permeable paving can be distinguished:

- **Porous pavements** : water is infiltrated across the entire surface
- **Permeable pavements:** materials such as bricks are laid to provide void space through to the sub-base, by use of expanded or porous seals

Impacts:

- **Store Runoff → Medium** *(Permeable paving stores rainfall-runoff in the sub-base and either releases it at a controlled rate, or infiltrates to groundwater.)*
- **Slow Runoff → Medium** *(Values for runoff reduction varied between 10%-100%, while peak flow reductions of between 12-90% were reported. Effectiveness can decrease significantly over time without sediment management Blanc et al (2012))*
- **Increase infiltration and/or groundwater recharge → None to Medium** *(Permeable paving can be designed to allow infiltration, unless local conditions do not allow it (for example where groundwater levels are high or there is soil or aquifer contamination))*
- **Water storage → Low to Medium** *(provides some storage and slowing of runoff from small drainage areas and in some cases route this, via infiltration, to soil and groundwater storage)*

Capital and maintenance costs:

- Capex → 40-90€/m^2 permeable paving area
- Maintenance → 1-5€/m^2 per year

3.2 Soakaways

Soakaways are buried chambers that store surface water and allow it to soak into the ground. They are typically square or circular excavations either filled with rubble or lined with brickwork, pre-cast concrete or polyethylene rings/perforated storage structures surrounded by granular backfill. Soakaways provide storm water attenuation, and storm water treatment. They also increase soil moisture content and help to recharge groundwater. They can also be used to manage overflows from water butts and other rainwater collection systems, or can be linked together to drain larger areas including highways. As a sub-surface infiltration device, a soakaway requires no net land take and it can be buit in many shapes.

Source: http://nwrm.eu/measure/soakaways

Impacts:

- **Store Runoff → Medium** *(They are designed to capture and infiltrate runoff up to the 1 in 30 year event (CIRIA, 2007).)*
- **Increase infiltration and/or groundwater recharge → High** *(The main function of this measure is collecting runoff and infiltrating it to the underlying soils.)*

- **Increase soil water retention → Low** *(Soakaways consist of a sub-surface structure with enhanced infiltration capacity and they could be considered to effectively increase soil water retention.)*

Capital and maintenance costs:

- Capex → > 90€/m^3 stored volume
- Maintenance → 0.25-1.25€/m^2 treated area

3.3 Infiltration Trenches and Swales

3.3.1 Infiltration trenches

Infiltration trenches are shallow excavations filled with rubble or stone. They allow water to infiltrate into the surrounding soils from the bottom and sides of the trench, enhancing the natural ability of the soil to drain water. Infiltration trenches reduce runoff rates and volumes and can help replenish groundwater and preserve base flow in rivers. They are best located adjacent to impermeable surfaces such as car parks or roads/highways where there levels of particulates in the runoff are low. They work best as part of a larger sustainable drainage treatment train. Infiltration trenches are also ideal for use around playing fields, recreational areas or public open space. They can be effectively incorporated into the landscape and designed to require minimal land take.

Source: http://nwrm.eu/measure/infiltration-trenches

Impacts:

- **Store Runoff → Medium**
- **Slow Runoff → Low** *(conclude that infiltration trenches are effective for runoff reduction for up to 1 in 30 year events (Blanc et al, 2012). The trench design must take in to account the infiltration rate of the underlying soil, to ensure effective operation. Blanc et al (2012) found in their review of literature that antecedent conditions can have a significant influence on performance. In addition, effectiveness can reduce significantly over time if high levels of sediment are allowed to enter the trench.)*
- **Increase infiltration and/or groundwater recharge → High** *(Infiltration trenches function by collecting runoff and infiltrating it to the underlying soils.)*
- **Increase soil water retention → Low** *(Infiltration trenches consist of a sub-surface structure with enhanced infiltration capacity and they could be considered to effectively increase soil water retention.)*
- **Reduce erosion and/or sediment delivery → Medium** *(They are effective in the removal of sediments where they are entrained in runoff in low concentrations, e.g. from roads. However*

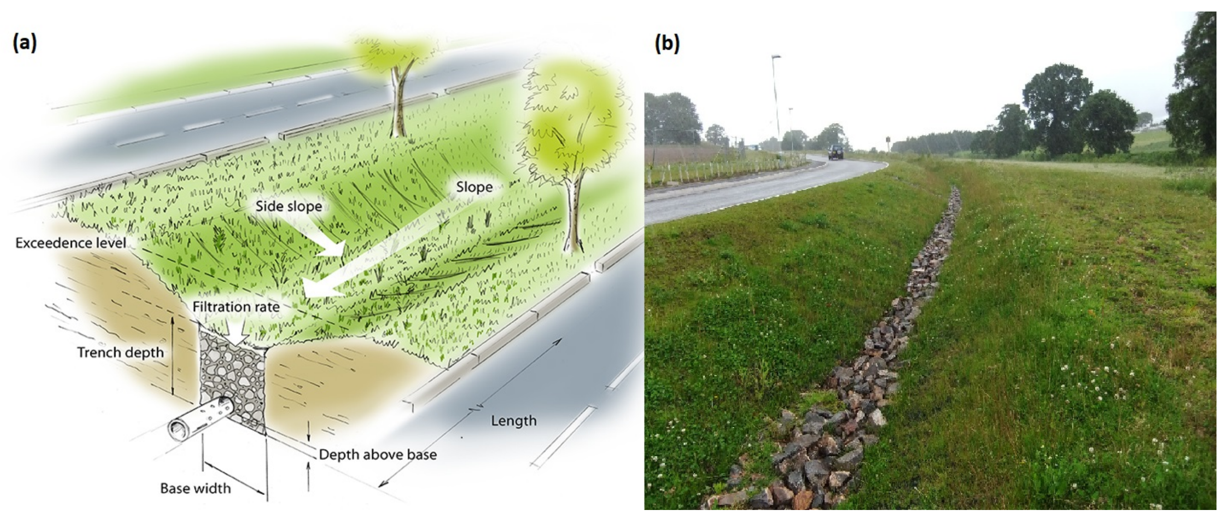
high levels of sediment loading are likely to significantly reduce the performance of a trench over time, and require pre-treatment.)

Capital and maintenance costs:

- Capex → 70-90€/m^3 stored volume
- Maintenance → 0.25-4.0€/m^2 surface area

3.3.2 Swales

Swales are broad, shallow, linear vegetated channels which can store or convey surface water (reducing runoff rates and volumes) and remove pollutants. They can be used as conveyance features to pass the runoff to the next stage of the SuDS (Sustainable Urban Drainage System) treatment train and can be designed to promote infiltration where soil and groundwater conditions allow. Swales are applicable to a wide range of situations. They are typically located next to roads, where they replace conventional gullies and drainage pipe systems. Other examples can be located in landscaped areas, adjacent to car parks, alongside fields, and in other open spaces.



Supplementary information on adaptation measures for addressing climate change impacts

Source: (a) https://help.xpsolutions.com/display/XDH2016v1/Swale (b) https://www.salixrw.com/product/vmax3-p550-permanent-turf-reinforcement-mat/attachment/7-vmax-p550-vegetated-swale/

This measure can contribute to water storage, climate change adaptation and mitigation, groundwater recharge, erosion/sediment control and flood risk reduction.

Impacts:

- **Store Runoff → Medium** *(the capacity of a swale should be designed to attenuate and treat a rain event with a 10 – 30 year return period, although there is potential for runoff rate control up to a 1 in 100 year event (Blanc et al, 2012))*
- **Slow Runoff → High** *(The literature they reviewed showed significant variations in the runoff reduction achieved from swales, but in general more than 50% reduction in mean runoff)*
- **Increase evapotranspiration → Low to Medium** *(it depends on the swale dimensions, residence time and type of vegetation)*
- **Increase infiltration and/or groundwater recharge → Medium** *(Infiltration increases where the residence time is higher, soil permeability is high and the infiltration surface is large.)*
- **Increase soil water retention → None to Low** *(Introduction of vegetation may over time increase the organic matter content and associated ability of the soil to retain water.)*
- **Reduce erosion → Medium** *(Sediment deposition is achieved through slowing runoff and the roughness of the vegetation)*
- **Reduce peak temperature → Low** *(Swales provide green areas and they can contribute to creating cool islands in urban landscapes)*
- **Absorb and/or retain CO_2 → Low** *(If a swale is added where no vegetation would otherwise be present, this will result in a localized increase in uptake of CO2, particularly if woody vegetation is included)*

Capital and maintenance costs:

- Capex → 15-80€/m^2 swale area
- Maintenance → 0.5-4€/m^2 swale area

3.4 Infiltration / Detention basins

Infiltration and detention basins are similar structures and the main difference between them lying in the ability to infiltrate stormwater. Infiltration basins allow storing and infiltration of rainwater and they're applicable in permeable surfaces. On the other hand detention basins contribute only in storing the rainwater and they're applicable in impermeable surfaces.

3.4.1 Infiltration Basins

Infiltration basins are vegetated depressions designed to hold runoff from impervious surfaces, allow the settling of sediments and associated pollutants, and allow water to infiltrate into underlying soils and groundwater. Infiltration basins are dry except in periods of heavy rainfall. They provide runoff storage and flow control as part of Sustainable Urban Drainage Systems (SuDS). Storage is provided through landscaped areas that allow temporary ponding on the land surface, with the stored water allowed to infiltrate into the soil.

Infiltration basins may also act as "bioretention areas" of shallow landscaped depressions, typically under-drained and relying on engineered soils, vegetation and filtration to reduce runoff and remove pollution. They provide water quality benefits through physical filtration to remove solids/trap sediment, adsorption to the surrounding soil or biochemical degradation of pollutants.

They are ideal for use as playing fields, recreational areas or public open space. They can be planted with trees, shrubs and other plants, improving their visual appearance and providing habitats for wildlife. They increase soil moisture content and help to recharge groundwater, thereby mitigating the problems of low river flows.

Source: http://archive.inside.iastate.edu/2008/0703/rain.shtml

Impacts:

- **Store Runoff → High** *(Infiltration basins are designed to store runoff to be infiltrated. They are typically used to treat runoff from a small number of properties in residential areas and are effective at storing runoff from this scale of drainage area. Infiltration basins are typically designed to infiltrate 50% of their storage volume within 24 hours of filling (CREW, 2012).Typically, infiltration basins are generally designed to capture and infiltrate runoff volumes for events up to the 1 in 30 year storm for the drainage area, but sometimes even for events up to 1 in 100 year storm. The effectiveness of the basin at providing this storage will depend on the condition of the underlying soil and the characteristics of the drainage area (CREW, 2012). Stored runoff is infiltrated into underlying soils/groundwater.*
- **Slow Runoff → High** *(If designed correctly with an appropriate outfall, infiltration basins are also effective at slowing runoff for events that exceed the storage/infiltration capacity of the basin.)*
- **Increase evapotranspiration → Low to Medium** *(The rate of evapotranspiration will depend on dimensions, residence time and type of vegetation. With dense vegetation and a relatively long residence time, evapotranspiration can be substantially increased, particularly if trees are planted.)*
- **Increase infiltration and/or groundwater recharge → High** *(Designed to store water to be infiltrated into underlying soils and groundwater. The infiltration performance of each basin will be unique based on specific site conditions and materials.)*
- **Increase soil water retention → None to Low** *(Introduction of vegetation may increase organic matter content over time, and the associated ability of the soil to retain water.)*

- **Reduce erosion and/or sediment delivery → Medium** *(Infiltration basins can effectively capture sediment in urban or rural runoff, thereby reducing sediment concentrations in downstream watercourses.)*
- **Reduce peak temperature → Low to Medium** *(Infiltration basins provide green areas. Depending on vegetation density, their dimensions and how widespread they are, they can contribute to creating cool islands in urban landscapes)*
- **Absorb and/or retain CO_2 → Low to Medium** *(If an infiltration basin is added where no vegetation would otherwise be present, this will result in a localized increase in uptake of CO_2, particularly if woody vegetation is included.)*

Capital and maintenance costs:

- Capex → 15-90€/m^3 detention volume
- Maintenance → 0.15-5.5€/m^2 basin area

3.4.2 Detention basins

Detention basins are vegetated depressions designed to hold runoff from impermeable surfaces and allow the settling of sediments and associated pollutants. Stored water may be slowly drained to a nearby watercourse, using an outlet control structure to control the flow rate. Detention basins do not generally allow infiltration. Detention basins can provide water quality benefits through physical filtration to remove solids/trap sediment, adsorption to the surrounding soil or biochemical degradation of pollutants.

Detention basins are landscaped areas that are dry except in periods of heavy rainfall. They are ideal for use as playing fields, recreational areas or public open space. They can be planted with trees, shrubs and other plants, improving their visual appearance and providing habitats for wildlife.

Supplementary information on adaptation measures for addressing climate change impacts

Source: https://www.sudswales.com/types/passive-treatment/detention-basins/

Impacts:

- **Store Runoff → High** *(Detention basins temporarily store runoff, then releasing it at a slower rate downstream. The capacity to store runoff is dependent on the design of the basin, which can be sized to accommodate any size of rainfall event)*
- **Slow Runoff → High**
- **Increase evapotranspiration → Medium** *(Some increased evaporation is likely to occur during storage. The rate of evapotranspiration will depend on dimensions, residence time and type of vegetation.)*
- **Increase infiltration and/or groundwater recharge → None to Low** *(Detention basins are not designed to allow infiltration to underlying soils and groundwater)*
- **Increase soil water retention → None to Low** *(Introduction of vegetation may over time increase the organic matter content and associated ability of the soil to retain water.)*
- **Reduce erosion and/or sediment delivery → Medium** *(They can effectively capture sediment in urban or rural runoff, thereby reducing sediment concentrations in downstream watercourses.)*
- **Reduce peak temperature → Low to Medium** *(Detention basins could provide some contribution to lowering peak temperatures in urban areas, similarly to other green spaces. Depending on vegetation density and how widespread they are, they can contribute to creating cool islands in urban landscapes.)*

- **Absorb and/or retain CO_2 → Low to Medium** *(If a detention basin is added where no vegetation would otherwise be present, this will result in a localized increase in uptake of CO_2, particularly if woody vegetation is included.)*

Capital and maintenance costs:

- Capex → 10-110€/m^3 detention volume
- Maintenance → 0.5-5€/m^2 basin area

3.5 Rain gardens

Rain gardens are small-scale vegetated gardens used for storage and infiltration.

Rain gardens are typically applied at a property level and close to buildings, for example to capture and infiltrate roof drainage.

The filtered runoff is then either collected and returned to the conveyance system (using an underdrain) or, if site conditions allow, infiltrated into the surrounding ground. Rain gardens should be planted up with native vegetation that is happy with occasional inundations. They are applicable to most types of development, and can be used in both residential and non-residential areas.

Source: https://www.designingbuildings.co.uk/wiki/Rain_garden

Impacts:

- **Store Runoff → Medium** *(Rain gardens are effective at capturing runoff from small and medium sized rainfall events, providing limited storage and encouraging infiltration.)*
- **Slow Runoff → Medium** *(In these cases, the ability to store and slow runoff is rarely quantified, although simplified sizing calculations are included. For example in Lambeth, London in the UK a reduction in peak runoff rate of 70-96% for a 1 in 2 year event, 8-39% for a 1 in 30 year storm, and 4-16% for a 1 in 100 year event is anticipated (URS, 2013))*
- **Increase evapotranspiration → High** *(Planting within rain gardens, particularly the use of trees, will increase evapotranspiration. Rates of evapotranspiration will depend on the dimensions, residence time and type of vegetation)*
- **Increase infiltration and/or groundwater recharge → High** *(Rain gardens may be designed to infiltrate captured storage, where appropriate with respect to underlying soils and groundwater. Infiltration will increase where the residence time is higher, soil permeability is high, and/or the infiltration surface is large.)*
- **Increase soil water retention → Low** *(Soil improvements, such as the addition of organic matter, are often included when installing a rain garden, and in any case the introduction of vegetation may over time increase the organic matter content and associated ability of the soil to retain water.)*
- **Reduce erosion and/or sediment delivery → Medium** *(Rain gardens will capture sediment in runoff, thereby reducing suspended solid concentrations downstream.)*
- **Reduce peak temperature → Low to Medium** *(The measure could provide some contribution to lowering peak temperatures in urban areas. Depending on vegetation density and how widespread they are, they can contribute to creating cool islands in urban landscapes.)*
- **Absorb and/or retain CO_2 → Low to Medium** *(If a rain garden is added where no vegetation would otherwise be present, this will result in a localized increase in uptake of CO_2, particularly if woody vegetation is included)*

Capital and maintenance costs:

- Capex → The construction cost of rain gardens will vary depending on the site preparation required and the type of planting selected. If the rain garden is excavated and new growing media installed, costs will be much higher. If the garden is not excavated and entails modification of an existing planted area, costs will be much lower, although the effectiveness of the garden may be compromised.

- Maintenance → A simple rain garden constructed in a domestic garden will have little cost over and above standard gardening time and cost for the homeowner. In contrast, rain gardens will require maintenance by municipal authorities, although these are not expected to be onerous and can be incorporated in to normal street cleaning and drainage maintenance activities.

3.6 Re-meandering

A river meander is a U-form taken by the river, allowing it to decrease water velocity. In the past, rivers have been straightened by cutting off meanders. Channelizing was also a way to gain land for cultivation. River re-meandering consists in creating a new meandering course or reconnecting cut-off meanders, therefore slowing down the river flow. The new form of the river channel creates new flow conditions and very often also has a positive impact on sedimentation and biodiversity. The newly created or reconnected meanders also provide habitats for a wide range of aquatic and land species of plants and animals.

Source: http://riverwatch.eu/en/the-morava-anniversary-project-2014

Impacts:

- **Store Runoff → Medium** *(By expanding the functional river area, re-meandering allows a slowing of runoff on the shores of rivers, therefore allowing increased storage, especially if the vegetation cover and the associated soil properties are prone to favor this storage.)*
- **Slow Runoff → Medium**
- **Store River Water → Medium** *(Increase of the stream length and reconnection of old meanders increase the storage capacity of the river.)*
- **Slow River Water → High** *(Re-meandering slows down flows by increasing channel length.)*
- **Increase evapotranspiration → Low** *(If the action of re-meandering locally leads to vegetation development, thus it can have an impact in increasing evapotranspiration.)*
- **Increase infiltration and/or groundwater recharge → Medium** *(Meanders create wet environments supporting infiltration and ground water recharge. By modifying land cover and sometimes removing legacy sediment, re-meandering can change soil capacity retention.)*
- **Increase soil water retention → Medium** *(The increasing impact is proportional to the length of the meander.)*
- **Reduce erosion and/or sediment delivery → High** *(By modifying the river profile and decreasing water velocity, re-meandering decreases erosion and increases sedimentation.)*
- **Improve Soils → Medium** *(Re-meandering, by modifying land cover in a larger river functional area, improves soil quality.)*
- **Reduce peak temperature → Medium** *(If the action of re-meandering locally leads to vegetation development, thus it will generate shadow on the river channel and decreasing water temperature.)*
- **Absorb and/or retain CO_2 → Low** *(If the action of re-meandering locally leads to vegetation development, thus it will imply a positive impact on CO_2 absorption. The low impact is due to the surface of the river functional area impacted by the increased vegetation cover, which is smaller than a restoration measure at the floodplain scale for example.)*

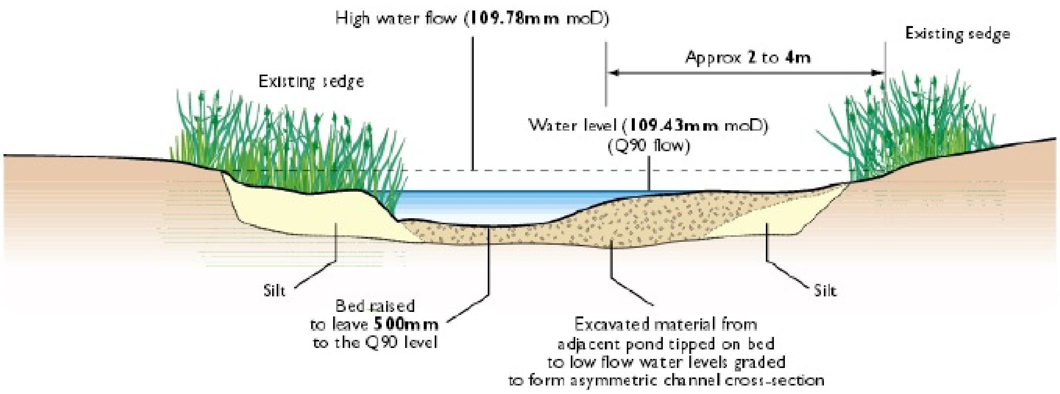
Capital and maintenance costs:

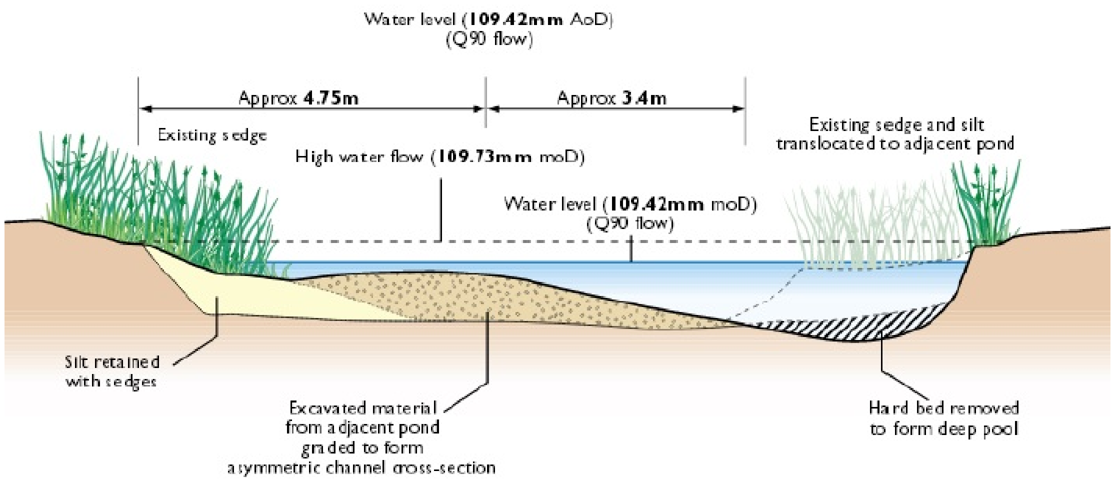
- Capex → 400000€/km
- Maintenance → n/a

3.7 Riverbed material restoration and re-naturalization

3.7.1 Riverbed material restoration

Riverbed material represents the sediment eroded upstream, transported by the river and deposited on the river floor. It can be composed of coarse and/or fine material. Its re-naturalization consists in recovering the nature-like structure and composition of the bed load, in particular the equilibrium between coarse and fine sediment. In case of deficit of coarse sediment leading to river incision, the main objective is to level-up the riverbed with this type of sediment, by reactivating bank erosion in terrains contributing to this type of sediment. It should be noticed that in case of excess of fine sediment causing inundations, silting of hydro-electric dams or degradation of fish habitats, the main objective is to control erosion on slopes and riverbanks providing this type of sediment.





Source: http://www.therrc.co.uk/pdf/manual/MAN_5_5.pdf

Impacts:

- **Store Runoff → Medium** *(By slowing down runoff, the latter will be increasingly stored)*
- **Slow Runoff → Medium** *(Runoff will be slowed down during flood events, due to a better connectivity with the floodplain)*
- **Store River Water → Medium** *(By allowing a better connection to tributaries and restoring a natural shape to the river bed, its storage capacity is increased.)*
- **Slow River Water → Medium** *(Slower drainage due to reconnection with the functional floodplain)*
- **Reduce erosion and/or sediment delivery → Low** *(In case of deficit of coarse sediment leading to river incision, the main objective is to level-up the riverbed with this type of sediment, by reactivating bank erosion in terrains contributing to this type of sediment, thus decrease in alluvial mattress erosion. But in case of excess of fine sediment causing inundations, silting of hydro-electric dams or degradation of fish habitats, the main objective is to control erosion on slopes and riverbanks providing this type of sediment)*

Capital and maintenance costs:

- Capex → n/a
- Maintenance → n/a

3.7.2 Stream bed re-naturalization

Streambed (or riverbed) represents the floor of the river, including each riverbank. In the past, riverbeds were artificially reconstructed with concrete or big stones, therefore modifying flows and decreasing fauna habitat and vegetation diversity. Those modifications were aiming at flood prevention or supporting changes of agricultural practices for example. This has led to uniformed flows in the rivers and often having effect of reducing travel time along the river. Streambed re-naturalization consists in removing some concrete or inert constructions in the riverbed and on riverbanks, then replacing them with vegetation structures, in order to avoid these damages and restore biodiversity. The re-naturalization of river beds and banks could have a high impact on the erosion process.

Supplementary information on adaptation measures for addressing climate change impacts

Source: http://chandrashekharasandprints.wordpress.com/2012/05/11/restoring-an-urban-river-bed-to-its-natural-eco-system-a-singapore-experiment/

Impacts:

- **Store River Water → Medium** *(By diversifying the channel width and depth, this measure can increase the water storage capacity of the river.)*
- **Slow River Water → High** *(By diversifying the river bed morphology and increasing its roughness, especially with vegetation, this measure helps slowing down the river flow.)*
- **Increase evapotranspiration → Low** *(Any replacement of concrete structure by vegetation structure will allow increasing evapotranspiration)*
- **Increase infiltration and/or groundwater recharge → High** *(The re-naturalization of the river bed restores the connectivity between the stream and the accompanying groundwater, therefore increasing stream-subsurface water exchanges.)*
- **Increase soil water retention → Low** *(Any replacement of concrete structure by vegetation structure will allow increasing soil water retention)*
- **Reduce erosion and/or sediment delivery → High** *(These techniques allow protecting the riverbed and the riverbanks against erosion, by improving their roughness, cohesiveness and biodiversity.)*
- **Improve Soils → Medium** *(These techniques allow the development and improvement of soil, due to the increasing presence and growth of vegetation.)*

- **Reduce peak temperature → Medium** *(Riparian vegetation (trees) could provide shadow for the river, reducing the peak temperature especially during the summer season while base flows occur.)*
- **Absorb and/or retain CO_2 → Low** *(Any replacement of concrete structure by vegetation structure will allow absorbing and/or retaining CO_2.)*

Capital and maintenance costs:

- Capex → Assess general costs would have no sense because they fully depend of the local context.
- Maintenance → n/a

3.8 Lake restoration

A Lake is a water retention facility. It can store water (for flood control) and provide water for many purposes such as water supply, irrigation, fisheries, tourism, etc. In addition, it serves as a sink for carbon storage and provides important habitats for numerous species of plants and animals, including waders. In the past, lakes have sometimes been drained to free the land for agriculture purposes, or have simply not been maintained and have silted up. Restoring lakes consists in enhancing their structure and functioning where they have been drained in former times.

Supplementary information on adaptation measures for addressing climate change impacts

Source: http://giizis13.wordpress.com/page/3/

Impacts:

- **Store Runoff → High** *(This measure, by enhancing the lake structure (size) and functioning, in particular by cleaning out the accumulated sediment, can increase its capacity for storing runoff. The runoff storage is equal to the total volume of the lake minus the volume already occupied by water.)*
- **Slow Runoff → Medium** *(This measure, by enhancing the lake structure (size) and functioning, can slow down the runoff)*
- **Store River Water → High** *(This measure, by enhancing the lake structure (size) and functioning, can increase its capacity for storing river water)*
- **Slow River Water → Medium** *(This measure, by enhancing the lake structure (size) and functioning, can slow down the river water)*
- **Increase evapotranspiration → Low** *(Evapotranspiration might change according to the surface area and/or extent of riparian habitat.)*
- **Increase infiltration and/or groundwater recharge → Low** *(A lake has more a storage function than an infiltration function. The impact of its restoration will be limited to the restoration of the associated alluvial groundwater.)*
- **Increase soil water retention → Low** *(Soil water retention might change according to the surface area and/or extent of the lake and its riparian habitat.)*

- **Reduce erosion and/or sediment delivery → High** *(As the river runoff and water are slowed down, sediment can deposit easier in the lake, therefore reducing sediment delivery on the river.)*
- **Improve Soils → Low** *(Soil quality might change according to the surface area and/or extent of the lake and its riparian habitat.)*

Capital and maintenance costs:

- Capex → 4000€/ha
- Maintenance → minimal (*Since these lakes have long lifespan, once in operation only minimal maintenance costs arise.*)

3.9 Dikes and Dams re-enforcing

Dikes and dams need regular maintenance and strengthening to keep their protection capacities and meet safety requirements. In addition, climate scenarios for sea level rise and extreme weather conditions can lead to reconsidering safety requirements and building new protections on identified weak points or heightening and strengthening existing ones. The design of existing dikes and dams can be modified to fulfil different purposes.

Re-enforcing dikes and dams can increase their stability and resistance against dike breaching, e.g. by strengthening the inner core of the dike, or improving characteristics of the dike's surface that contribute to the overall stability of the dike. Overtopping resistant dikes are wide and less steep than traditional dikes, and can be multifunctional (for example, for agriculture, recreation or transport).

Dikes can also be re-enforced by heightening, broadening or by adding spatial components. Heightening is the usual way to re-enforce dikes. Heightening provides coastal and riverside defense, but without integrated development or a combination of functions that a spatial solution may offer.

An overtopping dike can provide more safety against flooding than the typical single-line defenses. The measure reduces flood impacts (population exposed, production affected) by decreasing the sensitivity of people and assets in flood prone areas (i.e. the ability to manage water surplus).

Another option to reduce flood risk, other than strengthening the primary water defense structures, is to compartmentalize the region to be protected in zones, for example by dike ring areas. Compartmentalization either or both protects critical functions in the flood-prone area and reduces the flooded surface area. It diminishes the flood effects by dividing the area into compartments with the use of dikes.

Dams are barriers that are designed to impound or retain water for a variety of purposes, including water supply, irrigation, power generation, flood control, recreation and pollution control. Further, dams have great variation in size, ownership and operating rules.

In general dams are considered multy-purpose. The uses of dams are listed below:

- Flood control
- Hydropower
- Water Supply (storing water, irrigation)
- Sediment control
- Recreation (boating, fishing, swimming, hiking and camping)

Source: https://www.flickr.com/photos/neillwphoto/17188613186

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4 Climate Change Adaptation Measures related to forest fires

4.1 Fuel Treatment -Mechanical or Other non fire methods

A variety of methods that do not directly involve fire often are used to change vegetation composition and structure and alter fuels to reduce hazard. These include various *mechanical thinning and debris disposal techniques*. Non-mechanical methods can involve livestock grazing to reduce fine fuels. These methods can be used wherever they are economically viable, especially where using fire as a management tool is undesirable or carries high risks. One advantage of such methods is that they often can be applied with a greater level of control over the location, timing, and desired outcome of the treatment. Mechanical treatments are particularly suited for fuels management following natural disturbances such as severe storms, intense droughts, or insect outbreaks that radically change forest structure.

Impacts:

- Reduce fuels available for combustion and thus fire risk

Costs and Benefits:

These methods can be used wherever they are economically viable, especially where using fire as a management tool is undesirable or carries high risks. One advantage of such methods is that they often can be applied with a greater level of control over the location, timing, and desired outcome of the treatment.

An added advantage of mechanical treatments in forested ecosystems is the potential to use the removed woody material for other purposes. Forest thinning might result in excess stocking being utilized as sawlogs, wood chips, or specialty products made from small-diameter trees. If markets exist for the byproducts of the treatment, then there is a greater chance of treatments being economically viable.

4.2 Fuel Treatment -Prescribed burning

This measure encompasses the method of planned or prescribed fire (i.e. the deliberate use of fire to meet specific management objectives) for fuel treatment and alteration in order to reduce fire risk, protect community, and restore ecosystem.

Planned fires are a very effective way to remove unwanted vegetation for a variety of objectives, but a critical issue of any planned burning programme is mitigating the effects of smoke. An effective smoke management programme is then necessary when prescribed fires are applied. In fact, prescribed burning could be an alternative or complementary technique for fuel management, but carefully adapted to the different contexts and according to the existing territorial patterns (rural abandoned areas, wildland urban interface (WUI), productive rural regions, etc.)

Impacts:

- Prescribed fire is one of the more effective and cost-efficient means of managing vegetation for multiple purposes, including hazard reduction, ecosystem restoration or maintenance, silviculture, and others. In general, prescribed fire is an effective tool in areas with fire-adapted or fire-dependent vegetation that has evolved with fire.

Costs and Benefits:

Prescribed fire carries inherent risk, as fires can escape the prescribed perimeter or produce hazardous smoke if not managed correctly. Prescribed fire also varies widely in cost because of terrain, weather, and the spatial pattern of fuels, meaning that its application is not always economically feasible. Implementing and maintaining a prescribed fire regime, therefore, requires properly trained personnel, adequate resources, and the willingness on the part of the landowners and nearby communities to accept the costs and potential disadvantages of prescribed fire in exchange for the potential benefits.

4.3 Strengthen infrastructure to improve protection against forest forests

This measure includes the reinforcement /improvement of existing pre-suppression measures (fire breaks, forest roads, etc.)

Impacts:

- **Fire breaks** are designed to interrupt the continuity of fuels. In case of fire, the fire breaks normally will slow the rate of spread, thus enabling the ground fire fighting forces to reach the head of the fire and suppress it easily and with relative safety.
- **Forest Roads** are necessary and extremely important both for forest management and fire protection purposes.

4.4 Creating a mosaic of forest types including species with reduced flammability

This measure can be implemented by designing and developing less flammable or mixed ecosystems, as different species behave differently against forest fires and thus are more resistant to fires. This requires conducting appropriate studies to identify the appropriate species and appropriate sites for their development.

Impacts:

- Forest management techniques aiming at reducing the risk of forest fire ignition and expansion

4.5 Classification of forests according to the risk of fire and identification of high risk areas

Impacts:

- This measure is helpful for the forest fire management to minimize forest fire risk and avert damage

4.6 Reforestation /restoration actions of fire affected areas

This measure proposes reforestation / rehabilitation of affected areas with the use of appropriate forest reproductive material, the implementation of appropriate silvicultural measures and introduction of new techniques. Also, reforestation practices should be explored under the perspective of their suitability for adaptation to climate change.

Impacts:

- This measure prevents from floods and soil erosion and enables more rapid recovery for the burned areas

4.7 Establishment of a national forest registry

This measure proposes an establishment of a national forest registry (in countries lacking) with the registration of land uses, vegetation composition and ownership status. The registry should be produced or be compatible with Earth Observation information.

Impacts:

- This measure enhances forest protection and reduces fires related to public land violation

4.8 Modernization of the legal framework for fire prevention

Basic prevention regulations should address the following aspects: (a) forest management to avoid fires; (b) preventive silviculture measures in defensive and preventive infrastructures; (c) risk zoning to delimit areas regarding their fire risk and regulated land uses and activities according to fixed levels of risk; (d) establishment of risk periods in each country; (e) regulation on traditional and prescribed burnings; (f) social prevention measures (public awareness, governance mechanisms, etc.).

4.9 Recovery planning and prompt implementation to reduce erosion and watershed damage, flooding and risks to public safety

Indicatively, the sowing with graminaceous plants within the first 10 days after the fire in order to protect and stabilize forest in the first critical post-fire period.

Costs and Benefits:

- This intervention restricts the need for costly hydro-geomorphic projects, prevents erosion and floods and improves the useable water equilibrium

4.10 Implementation of policies to limit the abandonment of burnt areas and actions to prevent the spread of invasive species in burned areas

Impacts:

- This measure limits the change in the forest ecosystem profile and controls the increase of fuel abundance indirectly reducing future fire frequency.

4.11 Strengthening fire-fighting measures

This measure includes the strengthening of the fire-fighting system with significant investments in technical equipment, fire trucks and fire fighting resources and personnel training. This measure also includes the enhancement of volunteerism in forest fires suppression.

4.12 Incorporation of WUI areas in political/administrative instruments for forest fire management

The transitional areas between wildlands and urbanized spaces – the wildland urban interface (WUI) – represents an increasing fire risk factor and are highly vulnerable. These areas demand different policy and management measures regarding the biophysical and social components of the fire problem.

Tailored (e.g. higher resolution) spatial data is critical on the WUI extent, location and their evolution over time provide key information to develop effective fire planning in order to both avoid fire initiation and prevent negative impacts for the population.

Provisions for local emergency plans are also critical towards fire-adapted human communities to ensure public safety, reduce loss of property and direct more effectively fire response activities.

The WUI particularities call for social preventive measures regarding public information, social awareness and new governance mechanisms allowing existing stakeholders to participate in an integrated fire management scheme. Awareness raising of wildfire risk should be prioritized in wildland urban interfaces.

Finally, the WUI necessitates refining of forest related policies including urban spatial planning issues, fuel treatments around the structures, fire use activities and other owners' obligations, building material regulating codes etc.

4.13 Monitoring fires, modelling and forecasting fire danger

This measure proposes the use and of Earth Observation (EO) and Geographic Information System (GIS) techniques for real time fire detection and monitoring as well as post-assessment in order to support evidence-based decision making, increase preparedness, protect human lives, private property, infrastructures, and ecosystem services and enhance fire management. Furthermore, it proposes the development of short and long term fire danger forecasts in order to support wildfire management, prevention and preparedness.

Costs and Benefits:

Significant direct benefits typically derive from the combination of monitoring, modelling and forecasting systems with EWS (Early Warning Systems).

4.14 Awareness campaigns for behavioural change

This measure encompasses actions that promote awareness for the altered conditions under climate change and adaptation. However, not all stakeholders are aware and informed about their vulnerability and the measures they can take to pro-actively adapt to climate change. Public awareness is important to increase enthusiasm and support, stimulate self-mobilization and action, and mobilize local knowledge and resources. Raising political awareness is important as policy makers and politicians are key actors in the policy process of adaptation. Awareness raising requires strategies of effective communication to reach the desired outcome. The combination of these communication strategies for a targeted audience for a given period can broadly be described as ‘awareness raising campaign’. The aim of awareness raising campaigns most often differs between contexts but generally includes increase concern, informing the targeted audience, creating a positive image, and attempts to change their behaviour.

Impacts:

- Awareness raising is an important component of the adaptation process to manage the impacts of climate change, enhance adaptive capacity, and reduce overall vulnerability.

Costs and Benefits:

Awareness rising is a complex task with results hard to predict. Option may be efficient, leading to reduction of property damage at relatively low investment costs.

4.15 Establishment of a forest fire early warning system

Early warning systems can enhance the preparedness of decision-makers and private individuals for climate-related natural hazards and their readiness to harness favourable weather conditions. Early warning systems for natural hazards need to have not only a sound scientific and technical basis, but also a strong focus on the people exposed to risk, and with a systems approach that incorporates all of the relevant factors in that risk, whether arising from the natural hazards or social vulnerabilities, and from short-term or long-term processes. To be effective and complete, an early warning system needs to comprise four interacting elements namely: (i) risk knowledge, (ii) monitoring and warning service, (iii) dissemination and communication and (iv) response capability.

Impacts:

- The early warning systems can enhance the preparedness of decision-makers and private individuals to forest fires.

Costs and Benefits:

Early warning systems are usually cost-effective non-structural measures. Their cost, non-negligible in absolute terms, is extremely low in comparison with the potential amount of losses that these systems allow to reduce.

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5 Climate Adaptation Measures related to health

5.1 ***Early warning systems***

Use of consistent, standardised warning system activated and deactivated according to weather conditions. Issuing of early warnings and provision of appropriate advice through mass media and/or digital warning signs at certain places, is an essential measure for self protection of the population from an extreme weather event. Forecasting of heat waves and prediction of storms and floods are necessary and can be carried out in collaboration with research institutions.

Impacts
Less people exposed to high risk weather conditions. Lower risk of accidents and injuries due to floods. Fewer incidents of cardiovascular and respiratory failures.

5.2 ***Air conditioned public buildings***

Access to air conditioning is the most effective intervention to reduce mortality from heat waves (Kilbourne E.M., 1997). Municipalities could contribute by opening buildings to the public and by providing transportation for the citizens to reach the place. Priority should be given to people most at risk (elderly, very young persons, chronically ill patients, disabled persons and people without any other access to air conditioning).

Impacts: Less people exposed to high air temperatures. Fewer incidents of cardiovascular and respiratory failures.

5.3 ***Urban parks***

Municipalities could focus on conservation planning and urban park creation to protect residents from the effects of climate change. Green space such as parks, tree canopies and small rooftop gardens can help cool the urban landscape during heat waves. Urban parks can and also help at the urban storm water runoff problem, by collecting and cleansing storm water and preventing overflow in the streets. Water flowing over rooftops and roads also peaks up contaminants that include bacteria, oil and grease, metals and pesticides. Green infrastructure mimics how nature handles rainwater through the use of porous surfaces, rather than impervious surfaces like roadways, and it also helps removing a part of pollution.

Impacts

Cooling of the urban landscape: residents experience lower temperatures. Storm water runoff: fewer accidents due to streets overflow, residents not exposed to bacteria and chemical contaminants.

5.4 Strategies for public buildings restoration

Adaptation measures for civil protection should also take into account adaptive strategies for buildings. Municipalities could undertake the restoration of public buildings. More specifically, the changes can be summed up to the following points:

- Greater strain on building material fixtures, cladding and fasteners and strengthening of tile fixtures securely to the roofs to avoid wind damage.
- Use of low emissivity environmentally safe building paints to improve the thermal performance of the building and to reduce heat transfer and heat radiation.
- External shading for hot surfaces.
- Replacement of concrete and steel, where possible. These materials absorb and radiate heat, causing late afternoon temperature to rise.

Impacts

Reduced thermal emission from the buildings during afternoon: residents leaving close to the public buildings experience lower temperatures in the afternoon. Reduced risk for injuries from detached objects due to strong winds.

5.5 Water pollution monitoring

Monitoring of the water pollution is an essential adaptation measure for protecting public health as climate change may cause a broad range of water quality-based health concerns:

Seasonal and geographic changes in waterborne illness risk: Changing water temperature may mean that waterborne Vibrio bacteria and harmful algal toxins will be present in the water at different times of the year or in places where they were not previously threats.

Extreme precipitation events increasing exposure risk: Toxins produced by harmful algal and cyanobacterial blooms in the water may all be exacerbated by increased runoff, warmer temperatures and discharges from point sources of pollution.

Extreme weather leading to water infrastructure failure: Extreme weather events and storm surges will increase the risk that drinking water, wastewater and stormwater infrastructure will fail due to either damage or exceedance of system capacity. As a result, the risk of exposure to water-related pathogens, chemicals, and algal toxins will increase in receiving waters and, when that enters source waters may complicate drinking water treatment efforts.

Impacts:

Less people exposed to bacteria and chemical contaminants in the water.

5.6 Raising public awareness

With climate change, extreme heat events will become more frequent and intense. However, little is known about public awareness of heat warnings or behaviors during hot weather. Municipalities can raise the awareness about risk factors, symptoms of heat-related illness, and when and how to seek treatment. Outreach programs and education can help build awareness of heat island risks and establish a foundation for action. A city council can issue resolutions, a public statement documenting a group’s interest in heat island mitigation. This can be the first step in getting an initiative started.

Impacts

Prevention of incidents and health problems related to high air temperatures.

5.7 Pavements redesign

Pavements could be redesigned so that they reflect most of the solar radiation. The use of cool pavements can reduce the urban heat island effect. In addition, pervious pavements can reduce storm water storage and prevent overflow.

Impacts

Cooling of the urban landscape: residents experience lower temperatures. Storm water runoff: fewer accidents due to streets overflow.

5.8 Limitation of outdoor activities

More novel adaptation strategies target outdoor workers and activities during a heat wave through rational organisation of work schedules, such as start work early, take breaks often, scheduling most physical activity early in the morning or late in the afternoon.

Impacts

Less people exposed to high air temperatures during the hot hours of the day.

5.9 Strict controls/health inspections in food industry

Adaptation measures during heat waves could also contain advice on food hygiene, preparation and storage along with health inspections in food industry. In excessive temperatures, food spoils sooner and rates of food poisoning can increase. Food poisoning can increase dehydration and exacerbate the ill effects of heat.

Impacts:

Less people exposed to the risk of food poisoning.

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6 Climate adaptation measures related to the energy sector

6.1 Renovation of municipality buildings to Nearly Zero-Energy Buildings

Buildings represent the largest available source of cost effective energy saving and CO_2 reduction potential. “Nearly zero-energy building” means a building that has a very high energy performance. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby. Some interventions to achieve this goal are:

- Installation of photovoltaic solar modules
- Improving existing insulation to high performance insulation to limit the losses and thus limit the heating and cooling consumption
- Installation of a central heating network using wood pellet boilers in cases buildings heated electrically
- Installation of adjustable external slats to protect from the sun
- Replacement of existing windows with low-e double-glazed windows and frames with thermal break
- Replacement of existing lighting with LED
- Presence control for lighting and heating
- Appropriate reconstructions for natural night ventilation for summer comfort
- Renovation of the roof - Green roof
- Renovation of the facade

Impacts:

The renovation of municipality buildings can reduce in a high extent the energy demand for heating and cooling. Actually, the final energy (for heating, cooling, ventilation and lighting) savings after renovation rages from 60-70% (Vazquez et al. 2016)

6.2 Financial incentives for the Holistic Energy Efficient Retrofitting of Residential Buildings

Retrofitting include various types of insulation materials such as Aerobel/aerogel, starch micro-porous insulation, vacuum insulated panels, smart windows, surface coatings, multi-functional lightweight materials integrated with phase change material for thermal storage and integrated heat recovery panels. Energy efficient solutions will also be deployed including energy efficient lighting using LED and light pipes, energy efficient HVAC (Heating Ventilation & Air Conditioning) such as natural ventilation, passive heating/cooling, heat pumps integrated with heat recovery and thermal storage, and renewable energy systems based on solar thermal and photovoltaics.

Impacts:

- Cumulative annual energy savings of at least 80% measured against building performance before retrofit
- At least a 60% reduction of CO_2 emissions
- A global energy consumption (excluding appliances) of 50 kWh/m^2/year while reducing peak loads against the values measured before retrofit
- At least 80% energy saving for lighting over the average consumption of the installed base.

6.3 Cool Roofs

This adaptation measure refers on the installing of cool roofs to reduce the urban heat island effect. Cool roofs reflect more light and absorb less heat than traditional roofs. Or in more technical terms, cool roofs have both a high solar reflectance (or albedo) and a high thermal emittance, so that much of the heat that is absorbed is quickly radiated back to the atmosphere. As a result, cool roofs can be 10 to 15 °C cooler than traditional roofs.

Cool roof materials come in a variety of colors from light to dark and are available for both low-sloped and steep-sloped roofs. They work for a variety of building types and aesthetic requirements. Creating a cool roof can be as simple as spraying on a light-colored, paint-like coating. There are two basic types of coating that reflect more light and energy than a traditional roof: cementitious and elastomeric. Cementitious coatings contain cement particles. Elastomeric coatings include polymers to reduce brittleness and improve adhesion. Both types have a solar reflectance of 65 percent or higher when new and have a thermal emittance of 80 to 90 percent or more. Slightly more complex approaches include membranes that can be applied to the roof, roof tiles that reflect the sun much better than traditional tiles, cool-colored metal roofing, and asphalt shingles.

Impacts:

- Reduce the urban heat island effect
- Lower peak electricity demand, which can help prevent power outages
- Reduce power plant emissions, including carbon dioxide, sulfur dioxide, nitrous oxides, and mercury, by reducing cooling energy use in buildings

In addition cool roof can benefit a building and its occupants by:

- Reducing energy bills by decreasing air conditioning and needs
- Improving indoor comfort for spaces that are not air conditioned, such as garages or covered patios and finally
- Decreasing roof temperature, which may extend roof service life

Costs

Although costs will vary greatly depending on location and local circumstances, cool roof coatings on a low-slope roof might cost €7,5-€15 per square meter, while single-ply cool roof membrane costs vary from €15-€30 per square meter

6.4 Green roofs

Traditional roofs absorb sunlight and radiate heat into the surrounding air. Vegetation on green roofs shades the roof and cools the air through evapotranspiration. These effects cool green roofs by 37°C compared to traditional black roofs. The cooler roofs transfer less heat to the ambient air. Green roofs do not have as great a cooling effect on air temperatures as ground-level vegetation does, but they have the advantage of not taking up additional land and of keeping building occupants cooler

Green roofs are made up of several layers: a waterproof membrane to protect the underlying roof, a drainage layer, a growing medium such as soil, and the plants themselves. There are two basic types of green roof -extensive and intensive- vary in the depth of growing medium and the amount of vegetation. Extensive green roofs have a thinner layer of soil and vegetation and are the simpler, lower-maintenance option. Plants used on these roofs include sedum (a hardy flowering plant) and/or herbs that have minimal maintenance requirements.

On the other hand, intensive green roofs have deep layers of growing media that can support a diverse array of plants from herbs and sedum up to full-grown trees. Intensive green roofs are much heavier than extensive roofs because of their added depth, heftier plants, and retained water. As a result, they require more structural support. They also require irrigation and fertilization to maintain the plants. Intensive green roofs work well for commercial buildings or parking garages that have the necessary structural strength.

<u>Impacts</u>

Green roofs reduce the heat flux through the roof, and less energy for cooling or heating can lead to significant cost savings. Shading the outer surface of the building envelope has been shown to be more effective than internal insulation.

Other impacts are as follows:

- In summer, the green roof protects the building from direct solar heat.
- In winter, the green roof minimizes heat loss through added insulation on the roof.
- Energy conservation translates into fewer greenhouse gas emissions.

In addition, a concentration of green roofs in an urban area can even reduce the city's average temperatures during the summer, combating the urban heat island effect. Traditional building materials soak up the sun's radiation and re-emit it as heat, making cities at least 4 °C hotter than surrounding areas. A modeling study found that adding green roofs to 50 percent of the available surfaces in downtown Torodo, Canada would cool the entire city by 0.1 to 0.8°C (EPA, 2008a)

Supplementary information on adaptation measures for addressing climate change impacts

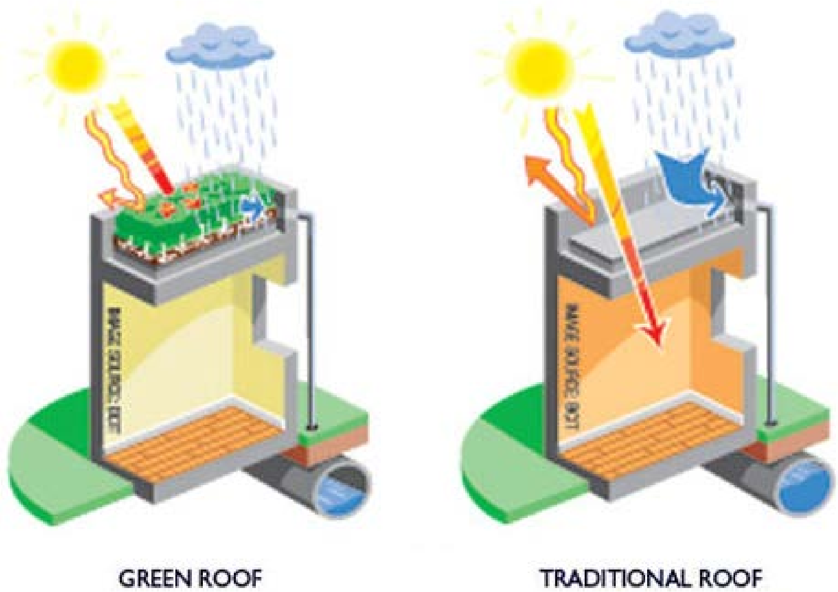

Figure 1 Benefits of a green roof compared to a traditional roof.

Figure 2 Temperature differences between a Green and Conventional Roof. Green roof is almost 40 °C cooler than the neighboring conventional roof

<u>Cost</u>

As mentioned before

6.5 Cool pavements

Cool pavement is a road surface that uses additives to reflect solar radiation unlike conventional dark pavement. Conventional dark pavements contribute to urban heat islands as they absorb 80-95% of sunlight and they can reach peak surface temperature of 48-67°C. Conventional pavements can transfer heat downward to be stored in the pavement subsurface, where it is re-released as heat at night contributing greatly to the urban heat islands (especially at nighttime) (EPA, 2012).

Existing dark pavement can be altered to increase solar reflectance (albedo) through whitetopping (covering of an existing asphalt pavement with a layer of Portland cement concrete) or by adding reflective coats and seals. New pavement can be constructed to increase albedo by using modified mixes, permeable pavements, and vegetated pavements.

Figure 3 Conventional pavement temperatures during summer. Temperature reaches up to 67°C (EPA, 2012)

Impacts

Installing cool pavements can be part of an overall strategy to reduce air temperatures, which can result in a wide range of benefits. As far as energy sector is concerned, the reduction of air temperature through the increase of solar reflectance from cool pavements could lower energy use. Actually, an increase of about 10-35% in the pavement reflectance throughout a city could potentially reduce air temperature about 0.6°C which would result in significant benefits in terms of lower energy use and reduces ozone levels (EPA, 2012). Resenfeld et al. (1998)

estimate over $90 million/year in savings from temperature reductions attributed to increased pavement albedo in the Los Angeles area.

Similarly, when permeable pavements evaporate water and contribute to lower air temperatures, they also provide other energy benefits. Permeable pavements can allow stormwater to infiltrate into the ground, which decreases stormwater runoff. With reduced runoff, communities may realize energy savings associated with pumping stormwater and maintaining conveyance structures. These cost savings may be significant in areas where there are old, combined sewers (where stormwater drains into the sanitary sewer system) (EPA, 2012)

Cost

Cool pavement costs will depend on many factors including the following:

- The region
- Local climate
- Contractor
- Time of year
- Accessibility of the site
- Underlying soils
- Project size
- Expected traffic
- The desired life of the pavement

Approximate installed cost for new construction of cool pavement varies from €0,8/m^2 to €8/m^2 depending on pavement type. Costs for maintenance of existing pavement to cool pavement varies from €0,8/m^2 to €5/m^2.

6.6 Urban forest

An urban forest is a forest or a collection of trees that grow within a city, town or a suburb. In a wider sense it may include any kind of woody plant vegetation growing in and around human settlements. Care and management of urban forests is called urban forestry. Urban forests may be publicly-owned municipal forests, but the latter may also be located outside of the town or city to which they belong.

Supplementary information on adaptation measures for addressing climate change impacts

Urban forests play an important role in ecology of human habitats in many ways: they filter air, water, sunlight, provide shelter to animals and recreational area for people. They moderate local climate, slowing wind and stormwater, and shading homes and businesses to conserve energy. They are critical in cooling the urban heat island effect, thus potentially reducing the number of unhealthful ozone days that plague major cities in peak summer months.

Impacts

The energy sector of an urban center benefits from urban forests mainly due to the capacity of the latter to reduce the air temperature and thus reduce the urban heat island effect. Trees and vegetation reduce heat in two ways. First, trees shade buildings, pavements, and other surfaces. Akbari et al. (1997) reveal that tree shade reduced the surface temperatures of walls and roof at two buildings by 11 to 25°C. In addition, Sandifer et al. (2002) examined the effects of vines on wall temperatures and found reductions of up to 20°C. Also, Scott et al. (1999) found that tree shading reduces the temperatures inside parked cars by about 25°C. This direct shading of the trees reduces energy needed to cool buildings.

The second way trees reduce air temperatures is through evapotranspiration. In this process, trees absorb water through their roots and emit it back into the air. Ambient heat converts the water into vapor, thus dissipating the energy. Evapotranspiration, alone or in combination with shading, can help reduce peak summer air temperatures. Measurements show that peak air temperatures in tree groves are 5°C cooler than over open terrain while temperatures over grass sports fields are 1 to 2°C cooler than over bordering areas (Huang et al. 1990, Kurn et al. 1994)

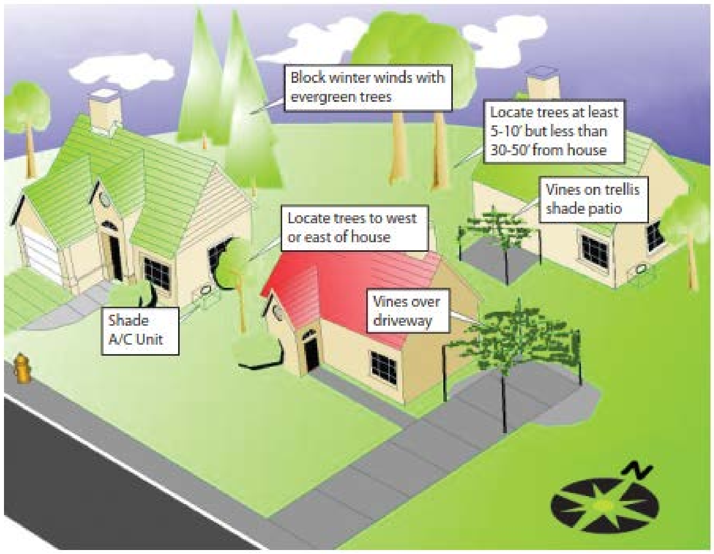

Figure 4. Tree placement to maximize energy savings. Picking the right trees and putting them in the right location will maximize their ability to shade buildings and block winds throughout the year (EPA, 2008b)

Cost

The primary costs associated with planting and maintaining trees or other vegetation include purchasing materials, initial planting, and ongoing maintenance such as pruning, pest and disease control, and irrigation. Other costs include program administration, lawsuits and liability, root damage, and tree stump removal. However, the benefits of urban trees almost always outweigh these costs. More precisely, the annual cost per tree is about €15-50 while the net benefits ranging from approximately €25-75 per tree (EPA, 2008b).

6.7 Economic incentives to reduce urban heat island

Incentives have proven to be an effective way to spur individual heat island reduction actions. Incentives from governments, municipalities, and other organizations can include below-market loans, tax breaks, product rebates, grants, and giveaways. Such initiatives that have already been implemented in other areas are as follows:

- Provision of coupons to homeowners to purchase trees from local nurseries
- Provision of free shade trees to residents to plant them around their homes
- Green and cool roof grant programs

- Provision of grants to building owners to encourage planting vertical gardens (green or living walls).

6.8 Economic incentives for Renewables and energy efficiency

Upfront costs are a major barrier to implementing energy efficiency projects in homes and businesses. An important goal of efficiency policies and programs is to help minimize these upfront project costs so owners are encouraged to invest in energy efficiency improvements and significant retrofits. Such initiatives that have already been implemented in other areas are as follows:

- Rebates provisions for lighting (replacement of conventional lamps with LED), upgrading of heating, ventilation, and air conditioning (HVAC) systems (e.g. replacing old thermostats), upgrading of water heater (e.g. installment of solar water heater), roof improvements (e.g. reflective roof), purchasing energy efficient appliances, improvement of building insulation, installation of photovoltaic panels

6.9 Demonstration projects and educational programs

Local governments, municipalities, universities, and other organizations have used projects to demonstrate a specific heat island reduction strategy and quantify its benefits in a controlled environment (e.g. energy savings). Documenting the project and its results can provide the data and publicity needed to develop larger initiatives, promote new technologies and help get them to market, and sometimes even encourage local economic development.

In addition educational programs that focus on teaching elements of residential energy efficiency to adults (homeowners, renters, builders and other housing professionals) and youth (students) can lead to an important behavioral change against issues such as the upgrading of home's thermal performance, putting efficient appliances in homes, implementation of actions reducing heat island effect etc.

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7 Climate Adaptation Measures related to ozone exceedances

Increases in ground level ozone (tropospheric ozone) pollution levels due to climate change may make it more difficult to attain or maintain ozone standards. This will need to be taken into account when designing effective ozone precursor emission control program. The adaptation plans regarding surface ozone concentrations are under the broader air-quality umbrella of adaption plans including emissions and particulate matter. However due the non linear relationships of ozone with its precursor emissions the impact of reduced emissions on ozone needs to be addressed more thoroughly. The adaptation measures can be divided into those taken by the authorities as well as voluntary. The first category of measures includes:

- Monitoring of air quality and strict inspections in service industry must be applied. Facilities should cut emissions by using the best pollution abatement technologies available
- Collection of data and an inventory must be completed
- Actions in areas of the Health Sector (preparation of facilities and staff).
- Implementation of measures for air quality improvement in urban areas must be enhanced.
- Enhance public awareness and education.

Voluntary measures may include:

- Self-protection measures (avoidance of external activities, on early morning exercise or in days with high levels of pollution)
- Changes in driving habits (refuel cars and trucks after dusk, combine errands and reduce trips, limit engine idling.
- Choose a cleaner commute — car pool, or use public transportation.
- Conserve electricity and set air condition at a higher temperature.

Benefits

Increased air-quality can lead to a reduction in lung diseases and as a result fewer premature deaths associated with poor air-quality.

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