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Down scaling of climate change scenarii to river basin level: A transdisciplinary methodology applied to Evrotas river basin, Greece

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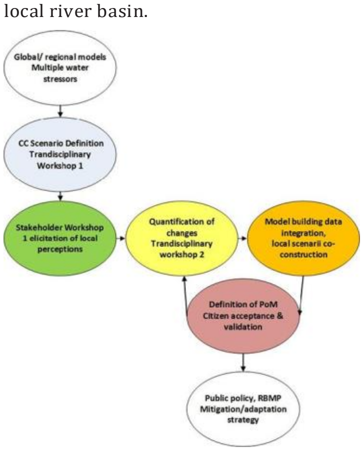
G R A P H I C A L A B S T R A C T

Transdisciplinary methodological framework to downscale global regional climate change scenario to local river basin.



a b s t r a c t

The Mediterranean region is anticipated to be (or, already is) one of the hot spots for climate change, where freshwater ecosystems are under threat from the effects of multiple stressors. Climate change is impacting natural resources and on the functioning of Ecosystem Services. The challenges about modelling climate change impact on water cycle in general and specifically on socio-economic dynamics of the society leads to an exponential amount of results that restrain interpretation and added value of forecasting at local level. One of the main challenges when dealing with climate change projections is the quantification of uncertainties. Modellers might have limited information or understanding from local river catchment management practices and from other disciplines with relevant insights on socio-economic and environmental complex relationship between biosphere and human based activities. Current General Circulation Models cannot fulfil the requirements of high spatial detail required for water management policy. This article reports an innovative transdisciplinary methodology to down scale Climate Change scenarii to river basin level with a special focus on the development of climate change narrative under SSP5-RCP8.5 combination called Myopic scenario and SSP1-RCP4.5 combination called Sustain- able scenario. Local Stakeholder participative workshop in the Evrotas river basin provide perception of expected changes on water demand under to two developed scenario narratives.

1. Introduction

Freshwater ecosystems are under threat from the effects of multiple stressors, including organic and inorganic pollution, land use changes, water abstraction, invasive species and pathogens (Navarro-Ortega et al., 2015; Thonicke et al., 2013). Little is known beyond the described effects of single stressors on the chemical and ecological status of water bodies and on their ecosystem functionality. This lack of knowledge limits our capacity to understand ecosystem responses to multiple stressors and to define a programme of measures that can improve the ecological status of water body as sought by the European Water Framework Directive. People rely on ecosystems to provide water related services. Climate change is impacting natural resources including water, land use and land use management and on the functioning of Ecosystem Services. The challenges (choice of models, values of variables, arbitration) about modelling climate change impact on water cycle in general and specifically on socio-economic dynamics of the society leads to an exponential amount of results that restrain interpretation and added value of forecasting at local level.

The Mediterranean region is anticipated to be (or, already is) one of the hot spots for climate change with a decline of precipitation up to over 50% in summer, severe increase in temperature and an increase in drought frequency and strength (Giorgi, 2006; Christensen et al., 2007; Field et al., 2012; Kjellström et al., 2013). Population increase and associated economical dependencies on water resources usage, cumulated with climate change will exacerbate the global water scarcity crises (Gosling and Arnell, 2016; Hanasaki et al., 2012), especially in the Mediterranean (Gampe et al., 2016; Haddeland et al., 2014). Koutroulis et al. (2016), found a similar reduction in freshwater yearly availability at regional scale using the recent CMIP5 simulations for the eastern Mediterranean. Nevertheless local assessment of water scarcity in Mediterranean basins, e.g. through hydrological modelling, is often limited by available data. To overcome this problem of bridging the data gap, and interpretation at local scale extensive field campaigns need to be conducted (Serra et al., 2016, Meyer et al., 2016; Gampe et al., 2016). Local data collection approaches are costly in terms of labour, computational demand and often still require additional data and expertise from multi-disciplinary teams and local expertise.

Stakeholders, the beneficiaries of ecosystem services (ES) managers of river bodies and landscapes play a key role in ecosystem service understanding and in providing insights to interpreted impact of Climate Change on water resources and usage. Due to the complexity of the challenge that is communicating over uncertainty management and producing meaningful output of the cascade of models for both academia, policy makers, and the wider public, a mixed methodology based on transdisciplinary approach and the involvement on local experts was developed during the course of the Globaqua project.

The EU-project 'GLOBAQUA -Managing the effects of multiple stressors on aquatic ecosystems under water scarcity' (2014–2019) aims to study the effects of multiple stressor on river basin subject to water scarcity in order to improve understanding of current management practices and identifying possible improvements in the management strategies to adapt or mitigate the impact of climate change. Six river basins affected by water scarcity either due to climatological pressures or to high variability in rainfall or multiple conflicting water uses, were identified. Four of those six river basins have been chosen for extensive field work and for several impact modelling activities: Adige (Italy), Ebro (Spain), Sava (Slovenia, Croatia, Serbia and Bosnia and Herzegovina) and Evrotas (Greece), (Navarro-Ortega et al., 2015). Modelling activities focus on the ecological status of the river ecosystems, on the assessment the role of emerging pollutants, other chemicals and geomorphological changes that act as stressors for the aquatic ecosystems. In this research project the role of climate change is also considered as a stressor. Beside modelling activities participative stakeholder's workshops were organised to understand the local context and functioning of Ecosystems at catchment level.

Complex topography and/or small size of the river basins require climate change information at regional to local scale, at high spatial resolution. The primary tools for providing future climate projections are coupled General Circulation Models (GCMs), which simulate climate changes under a range of possible future scenarios of greenhouse gas emissions (Gampe et al., 2016). These are based from the scenarios provided through various Representative Concentration Pathways (RCPs) that span a range of the radiative forcing of 2.6 to 8.5 W/m2 for the year 2100 (Van Vuuren et al., 2011). Currently, GCMs have spatial resolution of 100–250 km. Due to the additional constraint of providing an ensemble of projections over long time periods, GCMs cannot fulfil the requirements of high spatial detail required for water management policy and are, therefore, generally supplemented with statistical or dynamical downscaling to produce future climate projections at regional scales (Gampe et al., 2016).

One of the main challenges when dealing with climate change projections is the quantification of uncertainties, which can have different origins, such as emission scenario, model formulation and natural variability. Several different emission scenarios and climate models should be used to assess the uncertainties related to external forcing sampling a range of future possible climate outcomes (Jones and Nikulin, 2009). Furthermore, modellers might have limited information or understanding from local river catchment management practices and from other disciplines with relevant insights on socio-economic and environmental complex relationship between biosphere and human based activities.

In this context and in order to assess future water scarcity conditions, spatially distributed, integrated scenarios to drive various impact models are necessary to improve accuracy of land use and water use maps at local river basins. These simulations then assess future conditions of aquatic ecosystems, both in water quality and quantity, and in the end provide decision support (Huber-Garcia et al., 2017). A modelling framework is set up to develop integrated scenarios of changes in climate, land use and water management. These scenarios are based on innovative storylines around various Representative Concentration Pathways (RCPs) and Shared Socio-economic Pathways (SSPs), as established the Intergovernmental Panel on Climate Change (IPCC), and developed in a transdisciplinary collaboration with academia expert and with local experts.

Consequently, policy relevant implication of climate change impact on water scarcity at river basin scale, to ensure a best possible status of these aquatic ecosystems and functioning of ecosystem services (the Water Framework Directive in the case of European river basins) and also water usage policy for multiple usage (agriculture, energy, industry, etc…) require an innovative transdisciplinary approach.

Major challenges stem from the series of activities for the downscaling of these selected climate changes scenarii to local scale.

The objectives of this transdisciplinary research are:

- An attempt to develop a rigorous approach for downscaling integrated scenarios to catchment level: eventually a standard methodology to create CC local scenarii (Fig. 1);
- To describe and reflect on the IPCC scenarii co-construction at river scale level and land use modelling;
- To include local stakeholder's perception, choice and acceptance level in defining impact of climate change, mitigation, adaptation strategies and programme of measures.
- Reflect on transdisciplinary approach and creating added intellectual value to combine a wide range of expertise and paradigms to society and decision makers.

The overall trandisciplinary metholodological framework to downscale global regional climate change scenario taking tinto account multiple stressor on the mnagement of water resources at local river bassin consist on five (5) major activites (Fig. 1).

This article reports the first three main activities:

➢ Climate change scenarii definition, transdisciplinary workshop 1
➢ Stakeholder workshop 1 to elicit the perception of local experts
➢ Quantification of changes, transdisciplinary workshop 2

Since this article reports activities from several academic teams with a wide range of disciplines, detailed modelling protocols will not be addressed here but specific references for the ongoing work and forthcoming publications and project deliverable are provided.

2. Materials and methods

Fig. 2 presents the sequence of detailed tasks for the transdisciplinary methodological framework developed to downscale global regional climate change scenario to local river basin. The 5 major activities of Fig. 1 are split into specific activities. Although the overall transdisciplinary framework was developed beforehand, the detailed activities were developed in cooperation between project teams during the course of the project.

This chapter reports the steps to define climate change scenarii at local scale. The qualification and the qualification of CC impact at local scale are presented in chapter Results.

2.1. Climate change scenario definition

A transdisciplinary team made up of geographer, economist and sociologist within the project Globaqua, defined two scenarii based on a combination of SSP (Shared Social Pathway) and RCP (Representative Concentration Pathway) according to current IPPC work (IPCC, 2013, 2014; O'Neill et al., 2014).

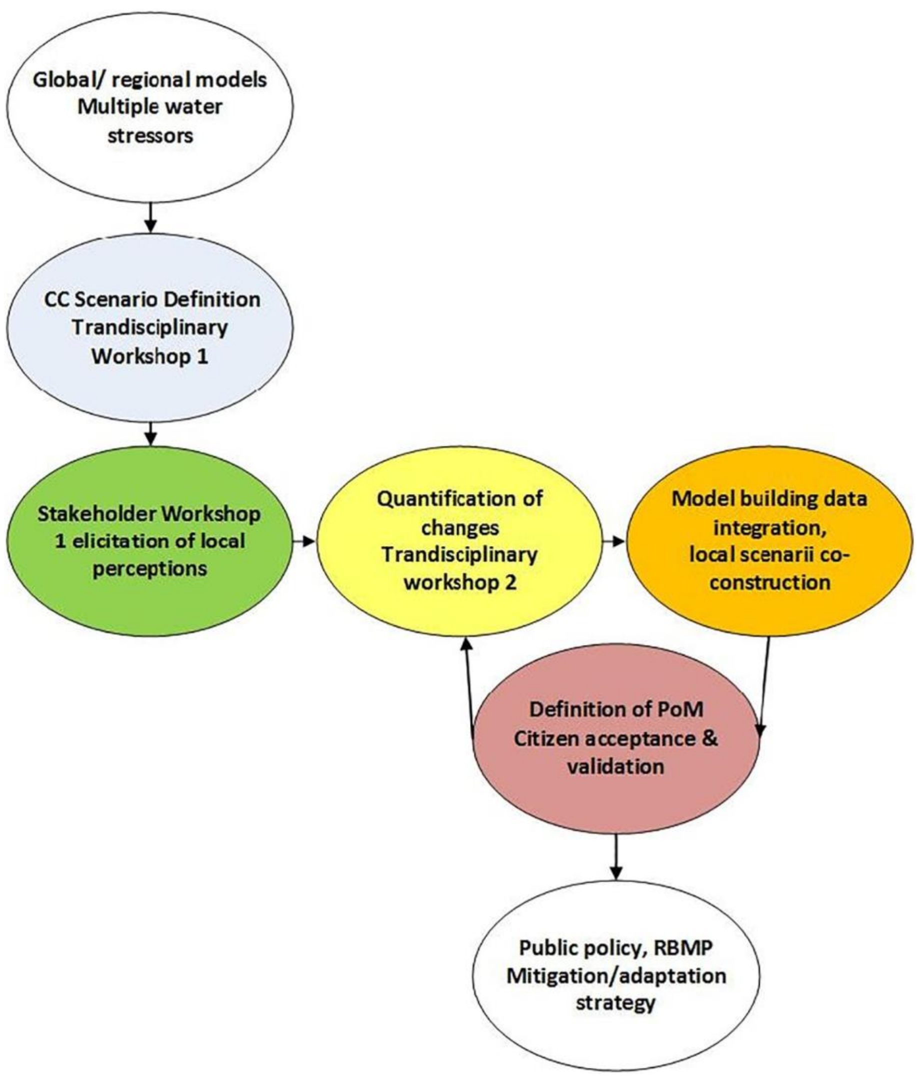


Fig. 1. Transdisciplinary methodological framework to downscale global regional climate change scenario to local river basin.

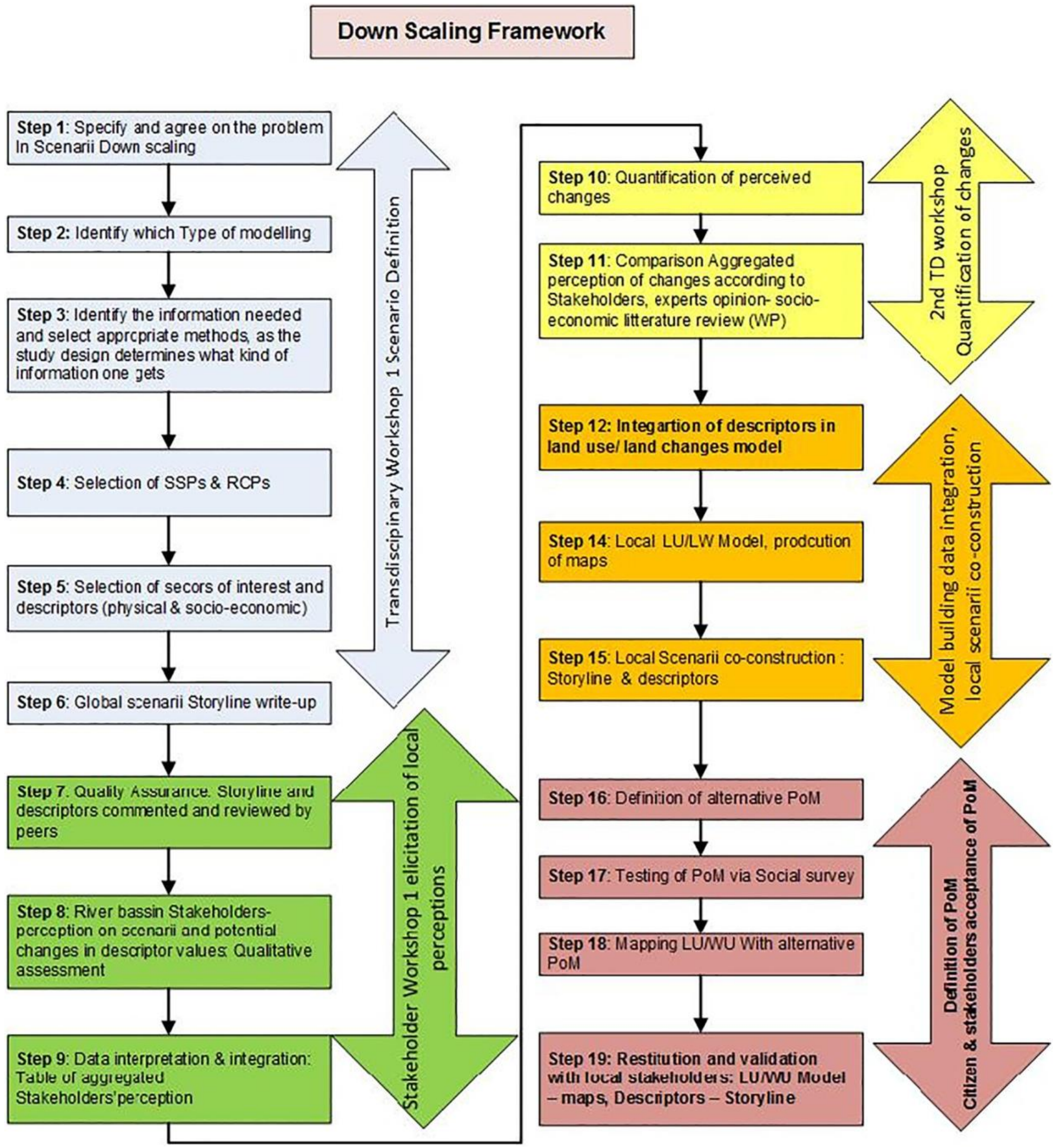


Fig. 2. Sequence of detailed activities for the trandisciplinary metholodological framework developped to downscale global regional climate change scenario to local river bassin.

In this research, scenarii are considered to be made of 2 elements: a storyline and the table of descriptors. It is a combination of socio-economic elements and trends. These scenarii are describing potential future at global scale, based on existing IPCC output. Based on experience within the Globaqua team and links with project Mars and Impression, it was decided to focus on two (2) combinations of SSP–RCPs only because of the modelling implications of numerous input and to project resources constrains.

The selected combination of SSP-RCP are:

- SSP 5-RCP 8.5 is called MYOPIC and represents an Extreme scenario with high CO_2 emission.
- SSP 1-RCP 4.5 is called Sustainable scenario and represent a scenario with low CO_2 emission.

Storyline 1 describes at global level the combination SSPs 5 with RCP 8.5. It is also referred as "MYOPIC" scenario or "short-term Economy rules" or "fossil fuel driven" and represents an Extreme scenario with high CO_2 emission.

Storyline 2 describes at global level the combination SSP 1 with RCP 4.5 is called "Sustainable scenario" or "protection of natural and Human capital" and represents a scenario with low CO_2 emission.

Climate change scenarios were developed tested and reviewed in the first transdisciplinary workshop (Step 1–4, Fig. 2). From the very concise narrative for SSP 1 and SSP5 (IPCC, 2013, 2014; O'Neill et al., 2014), the transdisciplinary team developed the storyline according to five (5) sectors of specific interest on water resources management: society and economy, Energy, environment, policies and water management (Step 5, Fig. 2).

The two global storylines are presented below. They are identical for all case study areas and represent the starting point from which the stakeholders will be able to give a qualitative value to the expected change in the river catchment per descriptor.

2.2. Storyline 1 – MYOPIC (extreme scenario with high CO_2 emission)

2.2.1. Society and economy

GDP per capita is growing at a faster rate than the 25-year average. Economic growth allows investment and growth in human capital (education and professional training). This enhances institutional building and social equity and produces technological advances. This type of growth has a negative effect on the quality and quantity of stock and flows of natural capital (natural resources NC). This negative effect is not integrated in production and consumption decisions and relevant policies: the negative impacts of economic development on the environment are not considered important by decision makers in the country. In summary, economic growth is driven by substituting natural capital with physical capital (technological development). We use all resources for economic growth and we rely on technologies to compensate the effect of Climate Change and depleting resources.

2.2.2. Energy

Energy demand increases and in response energy supply increases, but only in terms of making available more fossil fuel based energy. Increased supply is driven by technological advances making all fossil fuel resources cheaply accessible. Fossil fuel based energy (using conventional and non-conventional resources such as fracking) prevails, because policies are not promoting green energy. Investments in alternative energy sources and mitigation measures exist, but are limited. The rate of growth of CO_2 emission increases, compared to 2012.

2.2.3. Environment

Governmental environmental regulation is myopic (i.e. does not take into account long-term effects), while measures are only compensatory to climate change (reactive) and confined only to local concerns. Provisioning services (food, water, wood) are considered relevant as long as they are useful for economic growth (let's use it all) supporting profitable energy production. Other ecosystem services (i.e. Regulating, Supporting and Cultural) are only of local short-run economic relevance and rank low in the global political agenda.

2.2.4. Policies

Policies are myopic and driven by technological advancements, aiming to maintain GDP growth without considering the medium and long-term effects on natural capital and human well-being. Environmental policies rank low in the political agenda and their enforcement diminishes as time passes.

2.2.5. Water management

Water management is fragmented and does not integrate the effects of water services on water resources. Water is considered valuable, and hence managed with care, only as input in income generating production processes, for flood prevention and protection, and for drinking water and food production. We only care about water quantity and quality as long as it does not interfere with economic growth. All its non-use values, such as clean water for nature, biodiversity and cultural heritage, are ignored.

2.3. Storyline 2 – SUSTAINABLE (scenario with low CO_2 emission)

2.3.1. Society and economy

The GDP per capita is growing at a faster rate than the 25-year average. As the societal emphasis shifts from economic growth per se towards an increase in equity, social capital and especially natural capital, this growth slows down over the long term. The overall level of globalisation is relatively high with markets being globally connected. However, the focus is on regional production and low material growth trying to reduce the resource and energy intensity in production of goods and services. Economic growth allows for investments in environmental technologies and human capital, which in turn enhances the development of efficient and internationally collaborating institutions. All these factors enable solutions for both mitigation (high mitigative capacity) of and longer-term adaptation to climate change effects.

2.3.2. Energy

Investments in environmental technologies, together with the phase-out of subsidies for fossil fuels and with lower taxation, make renewable energies more attractive. Fossil fuels are used less and less, reducing also the CO_2 emissions compared to the present. As a result of the overall trend to reduce energy and resource use, the resource and energy efficiency increases. This leads to an overall decrease in energy demand.

2.3.3. Environment

Environmental sustainability is prioritized. The increasing effectiveness of institutions and a stronger cooperation and collaboration at different levels help to improve the management of local and global environmental issues over the longer term. Environmental impacts, such as air and water pollution, decrease and environmental conditions improve overall. Land use is strongly regulated to avoid negative envi-ronmental impacts.

2.3.4. Policies

The awareness of the society regarding the social, cultural and economic costs of environmental degradation is expressed in policies (e.g. directives), which try to assign financial incentives (e.g. subsidies, lower taxes) for development and sustainability goals. There is a strong focus on environmental protection and strong regulations, e.g. regarding land use.

2.3.5. Water management

Complementary to civil protection (flood protection and prevention) and water supply, the management of water resources is triggered by a strong will to achieve high environmental standards. Ecosystem services related to water are considered to be of high value. Integrated long term management is applied, addressing local as well as regional water issues. The economic situation allows the use of technical measures (e.g. filtration of drinking water) in water resources management, although non-technical measures of self-regulation are preferred (prevention of water body pollution).

Together, researchers and stakeholders, created the opportunity to adapt those two (2) global scenarii to the local river basin with local knowledge, preferences and perception, all of which provide insights and enable to ground academic work onto local reality.

2.4. Table of descriptors

For each sectors on interest on water management resources a list of environmental and socio-economic factors and descriptors were identified, discussed and selected during the transdisciplinary workshop 1. Table 1 presents the selected list of factors and descriptors of sectors potentially impacted by expected change in climate, submitted to local expert in local river basins.

For each scenario, a panel of local experts (also referred as the local stakeholders) was required to fill-in the table on the perceive degree of change of the factor descriptor below (Table 1). While the transdisciplinary workshop are within Globaqua experts (definition of the scenario and the drivers, steps 1–6), the stakeholder workshop are with external stakeholders (step 8). The need for external workshop is justified because project experts are scientists and do not cover the knowledge of tourism agriculture, urban planning, regional planning.

Table 1
Factors and descriptors of sectors potentially impactd by expected change in climate, submitted to local expert in local river basins.

Sector	Factor/descriptor	Expected change in EVROTAS	Explanation, comments
Society & economy	Growth per capita		
	Unemployment		
	Inequality Index		
	Urbanisation		
Energy	Use of fossil fuel (%)		
	Use of renewable resources (%)		
Environmental effects	Air quality		
	Biodiversity		
	Invasive species		
	Deforestation		
	Soil degradation		
	Water scarcity (quantity/quality)		
Water management	Technical measures		
	Non-technical measures		
Agriculture	Irrigated surface area (ha)		
	Industrial agriculture (yield levels)		
	Organic agriculture (yield levels)		
	Meat production		
	Use of pesticides		
	Area cover with water intensive crops (ha)		
	Organic fertilizers		
	Mineral fertilizers		
	Reuse of manure and by-products		
	Abandonment of land		
	Crop rotation		
	Erosion prevention		
	Soil Salinization		
Industry	Investment in technology to emission reductions		
	Level of emissions		
Residential	Water consumption/demand		
Tourism & recreation	Mass tourism		
	Selected tourism		
Policies	Protected areas		
	Water quality standards		
	Food security		
	Desalination for irrigation		

The local stakeholders bring the local knowledge and enrich the context over the conflicting usage over water resources.

In the workshop, stakeholders were asked to translate the global scenarios to their river basins and to attribute an expected change according to the following notation:

- significant decrease - - -
- moderate decrease –
- slight decrease -
- no change compared to the current situation 0
- slight increase +
- moderate increase ++
- significant increase +++

One might appreciate that the 2 storylines and the table of descriptors above, are already results in themselves and might be used in any river basin to assess the local perception of climate change impact on water resources use.

3. Results

This section first presents the activities "Stakeholder Workshop 1 elicitation of local perceptions" Fig. 1. Corresponding to steps 7–9 (Fig. 2). The second part of the results, focuses on the activity "2nd transdisciplinary Workshop quantification of changes" corresponding to step 10 and 11 (Fig. 2) and briefly introduce step 12.

3.1. *Local stakeholders workshop, elicitation of local perceptions*

The Evrotas Stakeholders Globaqua participative workshop took place on 4–5 June 2015 in the Museum of the Olive and Greek Olive Oil in Sparta, co-organised by HCMR, Wageningen Environmental Research, Athens University of Economic and Business and the municipality of Sparta. It was preceded by three days of preparation by HCMR and Wageningen Environmental Research, developing questionnaires and presentations, and discussing and translating all materials in order to guarantee their suitability for the local situation, including a test round of simultaneous translation of all presentations (Step7). Twenty-eight (28) stakeholders from various municipalities, regional authorities and corporations participated. After the introduction, which stressed the workshop's participative nature, and its role in ecosystem services valuation and the implementation of the WFD, an overview of the Globaqua Project was given, the field work conducted so far and the next sampling campaigns planned in Evrotas were described, and the ecosystem services concept and its conceptual framework were clarified. The activities related to the participative identification of Ecosystem Services and their relative importance to human activities are reported in Sub-Deliverable 10.3 (2017). In the penultimate session two scenarii, Myopic and Sustainable, were presented. Participants were asked to fill in individually the Table 1 regarding impacts of these scenarios on the Evrotas river basin (Step 8) to translate the global scenarios to their river basins and to attribute an expected change according to notation presented above.

3.2. *Qualification of impact of 2 climate change scenarii by local experts*

Aggregated perceived expected changes are reported for the case study of Evrotas (Greece), Aggregated perceived expected changes for the case study of Adige (Italy), Ebro (Spain), Sava (Slovenia), Anglian (UK) and Souss Massa (Morocco) are reported in SubDeliverable 10.3 (2017).

The participants were given the following explanation: "A scenario is made of 2 elements: a storyline and the table of descriptors. A storyline is a short story describing a potential future. It is a combination of socio-economic elements and trends. These scenarii are describing potential future at global scale, based on IPCC (International Panel on Climate Change) work."

In Table 2, the frequency of each notation (—, –, - 0, +, ++, +++) is reported for each descriptor. The highest frequency is highlighted in orange and the second highest in yellow (if and only if, first and second highest score are separated by one degree).

The aggregation of perception is a challenge in itself because if represent the diversity of opinions. Additionally the sample of expert is not suitable for a statistical treatment. Count of occurrence of answers was selected as the most suitable method to identify and aggregated perception.

Aggregation of opinion on changes are more stringent (high cumulated frequency of scores) for the sustainable scenario than for the Myopic scenarios where the spread of cumulated frequency of scores is larger. In other words, there is a larger consensus on the perceived expected changes for the Sustainable scenario than for the Myopic scenario.

3.3. *Reconciliation between 'project expert' and 'local stakeholder' opinion*

In order to make the scenarios meaningful for the river basins manager and for modellers, project experts and stakeholder opinions were

Table 2
Aggregated perception of level of changes in socio-economic descriptors for two climate change scenarii at catchment level, Evrotas River Basin, Greece.

		MYOPIC Scenario SSP 5 with RCPs 8.5									SUSTAINABLE Scenario SSP 1 with RCP 4.5								
Sector	Factor/descriptor	Total -3	Total -2	Total -1	Total 0	Total 1	Total 2	Total 3	Total resp	Aggregatred Perceived change	Total -3	Total -2	Total -1	Total 0	Total 1	Total 2	Total 3	Total resp	Aggregatred Perceived change
Society & Economy	Growth per Capita	0	2	0	2	6	6	0	17	1	0	0	1	7	6	2	0	17	1
	Unemployment	0	5	4	1	5	2	0	17	-1	0	1	8	6	2	0	0	17	-1
	Inequality Index	0	1	3	2	2	8	1	17	2	1	2	7	4	2	1	0	17	-1
	Urbanisation	0	0	2	2	5	5	3	17	1	3	0	7	4	2	1	0	17	-1
Energy	Use of fossil fuel (%)	0	1	1	2	3	6	4	17	2	1	5	8	1	2	0	0	17	-1
	Use of renewable resources (%)	3	4	1	4	4	1	0	17	0	0	0	0	0	8	7	2	17	2
Environmental Effects	Air Quality	5	5	6	0	1	0	0	17	-2	0	0	2	0	7	8	0	17	1
	Biodiversity	4	10	1	0	2	0	0	17	-2	0	0	1	1	7	5	3	17	1
	Invasive species	1	2	1	1	7	4	1	17	1	0	2	3	5	5	1	0	17	0
	Deforestation	1	2	2	1	4	6	1	17	1	3	2	7	2	2	0	0	17	-1
	Soil Degradation	3	2	0	0	3	7	2	17	2	3	4	6	2	2	0	0	17	-1
	Water Scarcity (quantity/quality)	2	3	1	1	2	6	1	17	1	2	2	5	4	3	0	0	17	-1
Water management	Technical Measures	0	2	0	3	6	6	0	17	1	1	1	0	5	7	2	0	17	1
	Non-Technical Measures	0	1	2	5	5	2	1	17	1	1	0	2	4	4	5	1	17	1
Agriculture	Irrigated surface area (ha)	0	2	1	0	5	7	2	17	2	0	1	4	2	9	1	0	17	1
	Industrial agriculture (yield levels)	0	0	1	0	4	11	0	17	2	0	2	7	2	6	0	0	17	-1
	Organic agriculture (yield levels)	1	5	5	3	2	1	0	17	-1	0	0	0	3	4	8	2	17	2
	Meat production	0	1	2	0	8	5	0	17	1	0	1	2	3	9	1	0	17	1
	Use of pesticides	0	0	0	0	3	7	7	17	2	2	3	4	6	2	0	0	17	-1
	Area cover with water intensive crops (ha)	0	0	0	0	3	10	3	17	2	1	2	5	4	4	1	0	17	0
	Organic fertilizers	1	3	5	2	5	0	1	17	-1	0	0	0	1	7	7	2	17	2
	Mineral fertilizers	0	1	0	0	3	10	3	17	2	1	5	5	4	2	0	0	17	-1
	Reuse of manure and by-products	0	5	3	4	3	1	0	17	-1	0	0	0	0	8	6	3	17	2
	Abandonment of land	1	2	0	1	5	2	6	17	1	0	4	4	8	1	0	0	17	0
	Crop rotation	1	5	4	1	4	1	0	17	-1	0	0	0	3	8	5	0	17	1
	Erosion prevention	1	4	9	2	0	0	0	16	-1	0	0	2	2	8	5	0	17	1
	Soil Salinization	1	4	1	1	4	2	3	16	1	0	3	6	4	3	1	0	17	-1
Industry	Investment in technology to emission reductions	1	2	2	1	8	1	0	16	1	0	0	1	1	4	8	3	17	2
	Level of emissions	0	1	1	0	3	8	2	16	2	0	6	6	2	2	1	0	17	-1
Residential	Water consumption/demand	0	0	0	4	4	6	1	16	1	0	0	7	3	6	1	0	17	0
Tourism & recreation	Mass tourism	0	1	1	3	5	5	1	16	1	1	0	1	4	9	2	0	17	1
	Selected tourism	1	3	3	4	3	2	0	16	0	0	0	0	1	6	6	4	17	2
Policies	Protected areas	2	4	3	5	1	1	0	16	-1	0	0	0	1	10	4	2	17	1
	Water quality standards	1	3	6	2	2	1	0	16	-1	0	0	0	1	9	6	1	17	1
	Food security	0	0	4	2	6	3	1	16	1	0	0	1	7	7	2	0	17	1
	Desalination for irrigation	0	3	1	3	3	4	1	16	1	0	1	2	5	6	2	0	17	1
		Total -3	Total -2	Total -1	Total 0	Total 1	Total 2	Total 3	Total resp	Aggregatred Perceived change	Total -3	Total -2	Total -1	Total 0	Total 1	Total 2	Total 3	Total resp	Aggregatred Perceived change

considered. Project experts are the scientists working on the GLOBAQUA project that have deep knowledge of the different aspects of environmental management. Stakeholders and project expert opinion were considered to extract an overall downscaling factor Table 3).

Local Stakeholders and project experts input were reconciled taking into consideration existing literature on future trends. The results of the reconciliation between the two (2) group of perception is the value in the column "downscaled ". Where perceptions are diverging, the descriptor was discarded. Where perceptions are indicating the same trend on the 7-point Likert scale, scores of perception were averaged.

In the case of the Sustainable scenario the following can be said. Urbanisation should be expected to be fast Gossop (2011), which support

Table 3
Downscaled Scenarii based on project experts and local stakeholder, Evroats, Greece.

Sector	Descriptor	Sustainable scenario			Myopic scenario		
		Project experts	Stakeholder	Downscaled	Project experts	Stakeholder	Downscaled
Society & economy	Growth per capita	++	0		+++	+	+2
	Unemployment	—	+		—	0	
	Inequality Index	—	−	−2	−	++	
	Urbanisation	+	−		+++	++	+2.5
Energy	Use of fossil fuel (%)	—	−	−2.5	+++	++	+2.5
	Use of renewable resources (%)	+++	++	+2.5	0	+	
Environmental effects	Air quality	++	++	+2	−	−	−2.5
	Biodiversity	++	++	+2	−	−	−2.5
	Invasive species	—	−		+++	+	+2
	Deforestation	—	−	−1	++	+	+1.5
	Soil Degradation	—	−	−1.5	++	++	+2
	Water Scarcity	—	−	−1.5	+++	++	+2.5
Water management	Technical measures	+	+	+1	−	++	
	Non-technical measures	+++	+	+2	−	−	
Agriculture	Irrigated surface area (ha)	—	−	−1.5	++	+	+1.5
	Industrial agriculture	—	0	−1	++	+	+1.5
	Organic agriculture	+++	++	+2.5	−	−	−1.5
	Meat production	—	−	−1.5	+	+	+1
	Use of pesticides	—	−	−2	++	++	+2
	Area cover with water intensive crops (ha)	—	−	−2	−	+	
	Organic fertilizers	—	+		−	+	
	Mineral fertilizers	—	−	−2	++	+	+1.5
	Reuse of manure and by- products	++	++	+2	+	0	
	Abandonment of land	—	−	−1	+	+	+1
	Crop rotation	+++	++	+2.5	+	−	
	Erosion prevention	+++	+	+2	+	−	
	Soil Salinization	—	−	−1.5	+	+	+1
Industry	Investment in technology to emission reductions	++	++	+2	0	+	
	Level of emissions	—	−	−1.5	+++	++	+2.5
Residential	Water consumption/demand	—	−	−1.5	0	+	
Tourism & recreation	Mass tourism	—	−	−1.5	++	+	+1.5
	Selected tourism	+++	+	+2	0	0.5	0
Policies	Protected areas	+++	++	+2.5	0	−	
	Water quality standards	+++	+	+2	0	−	
	Food security	++	+	+1.5	+	−	
	Desalination for irrigation	—	−	−1.5	+	0	+1

project experts' opinion. With regards to irrigation, the experts stated that this variable will be significantly increasing, whereas the stakeholders stated that it will be slightly increasing. Hanasaki et al. (2012) claim that under SSP1, this variable will be increasing, however the rate will be at 0.06% at a global scale, meaning that a rather small increase will take place. Therefore the literature favours stakeholders' opinion. The production of meat is expected to be decreasing by the experts and increasing by the stakeholders. A rational argument is that since this scenario concerns the adoption of policies that protect the environment, it should be expected that consumers would prefer environmental friendly options for their nutrition, such as organic products, less meat, which leads to a great amount of pollution (Kumm, 2002). Therefore, although meat is consumed under this scenario its production rate should be decreasing to corresponds to the underline hypothesis of SSP1. Furthermore, the EC (2015) expects that the growth of meat production will decrease to reach that of population growth. Concerning water consumption, the opinion of the GLOBAQUA experts seems to be in line with that of the MARS project that expect that both energy and water consumption will decrease substantially. Concerning the area covered with water intense crops, it can be observed that experts believe that this will be highly decreasing in the future, whereas stakeholders believe that no change will take place. Since this scenario is characterised by environmental awareness and policies that lean towards the protection of the environment, it should be expected that instead of water intensive crop, water-stressed resilient crops would be cultivated instead. Therefore, the area of water intensive crops should be expected to decline as this will be substituted by areas where crops with low requirements of water are planted.

Under the Myopic scenario, experts and stakeholders disagree as to how the area covered with water intensive crops will evolve. Experts state a highly negative growth rate, whereas stakeholders state the opposite. This is expected as the two groups adopt different hypothesis. Experts consider that under SSP5, less water intensive crops will be developed and used, whereas stakeholders most likely think that due to increase in production of conventional water intensive crops, a larger share of land will be required. Furthermore during the local stakeholder workshop, a large number of participants "could not believe this scenario" and mentioned that "it should never happen". Since this scenario is technology driven and capital is used to substitute resource losses, experts' opinion could more easily be considered as more valid. Quality standards and policy instruments should not be considered to demonstrate a significant change from the current status, since SSP5 makes the hypothesis that policies do not aim at conserving or enhancing the environment. In the case of water consumption, it is expected to be increased (Oki and Kanae, 2006). Experts stated zero, because they expect that the water consumption will keep on rising as has been the case during the last years. On the other hand, the stakeholders consider that water consumption will continue to increase.

Complete description of reconciliation between local experts, project experts and the literature can be found in Sub-deliverable 2.5 (2018).

3.4. Quantification of aggregated expert's perception of impact of climate change scenarii on local water resources

The quantification of perceived change is a necessary step (step 12, Fig. 2) to enable modellers to produce land use demand, water use

Table 4
Translation of scenario descriptor values from the stakeholder workshops to percentage changes for model input.

Descriptor value	0	0/+ 0/-	+ -	+/++ -/- -	++ - -	++/+++ - -/- - -	+++ - - -
Change [%]	0	2.5 ± 2.5 −2.5 ± 2.5	5 ± 2.5 −5 ± 2.5	10 ± 2.5 −10 ± 2.5	15 ± 2.5 −15 ± 2.5	20 ± 2.5 −20 ± 2.5	25 ± 2.5 −25 ± 2.5

map and associated simulation. The Tables 3 above, provides a useful overview on the development trends but the information is still available in a qualitative way. In order to translate these trends into numbers, modellers, economist, sociologist and environmentalist compared them with values found in literature such as the River Basin Management Plans, institutional projections or other scientific studies. If no values could be found, the just mentioned final factors were used as reference taking also into account past trends. For every 0.5 factor value, a change of approx. 2.5% was assumed. The detailed method is described in Sub-Deliverable 2.6, 2017. The results of the quantification of perceptions impact of climate change scenarii on selected descriptor is a Look up table for model parameters, Table 4.

Each descriptor for each scenarii, per case study are was subsequently allocated a modelling value representing the expected change in order to produce land use demand and water use demand (Sub-deliverable 2.6, 2017).

4. Discussion

Implementing transdisciplinary research is necessary to overcome the complexity of challenges raised by the modellisation of climate change on water resources and on the impact of human activities. Nevertheless, transdisciplinary work is challenging in itself, first because it requires experts from several disciplines to leave their confidence zone to find consensus. Consensus are of different nature: on concept, on the methodology, on respective efforts to produce intermediary results other teams are building up. It also requires effort to communicate with experts in other fields with other types of skills and competences. Discussion are necessary to improve communication between experts within the same field and within totally different disciplines. Translation of concept is crucial to enable to work together but also to communicate with local experts and to take back their input; not only the language but the clarity and the meaning are important.

The participative workshops gathered the perception of local experts on the value and importance of their natural environment. Specifically, we assess the opinion of local impact of climate change and effect of pollution in the freshwater ecosystem. Usually land use and land change map modelling have limited input from local perception of change. The purpose of this research was to add a local and a social dimension to Climate change modelling. Our approach enables us to present decision-makers with a more accurate and comprehensive understanding of the potential competences of policy and impact on climate on the management of natural resources especially water.

The aggregation of perception is a challenge in itself because if represent the diversity of opinions. Diversity of opinion exists between local stakeholders and with project experts. Additionally the sample of expert is not suitable for a statistical treatment. The local experts had room to discuss some descriptors and could comment their appreciation. The number of comments was rather limited. The workshop setup and time constrains did not enable a sound discussion on each descriptors. The value of participative workshop whether between academic experts or local expert is slowly gaining credit. It remain nevertheless challenging to find resources to meet all objectives for sound discussions and consensus building.

The extended methodology to Down scaling of Climate Change scenarii to river basin level, is only partially reported in this article. Reporting such a methodology in the format of an article also demands for arbitration in the choice of step to be described. The literature on modellisation of impact of climate change and on water scarcity is rich in term of physical model, but is still fairly limited in it appreciation of transdisciplinary and local stakeholders' added value for input and interpretation of intermediary results.

Arbitration were made in each step of the methodology, starting with the definition of scenario, the selection of SSP-RCP combination to the definition of sectors and descriptors until the integration of descriptors in land and water use model and the production of programme of measures to be tested in a social survey at local catchment.

The final activities of the methodology (definition of Programme of Measures, citizen and stakeholders acceptance) is to assess the impact of multiple stressors of on ecosystem services based on each climate change model and response on specific programme of measures in order to close the gap between existing PoM and the WFD'objective of good ecological status, under expected climate change conditions. The presentation of programme of measures and level of acceptance of local citizen will be reported in Sub-deliverable 10.4 (2018) par of main deliverable 16, to be published (Dec 2018).

This final part could be considered as an iterative process and could become embedded in the PoM themselves as a mean to monitor policies (water allocation management, agricultural policies, land use policies etc…) and eventually to produce evidence based policies.

Transdisciplinary research is a work on progress.

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