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Adaptation strategies for water supply management in a drought prone Mediterranean river basin: Application of outranking method

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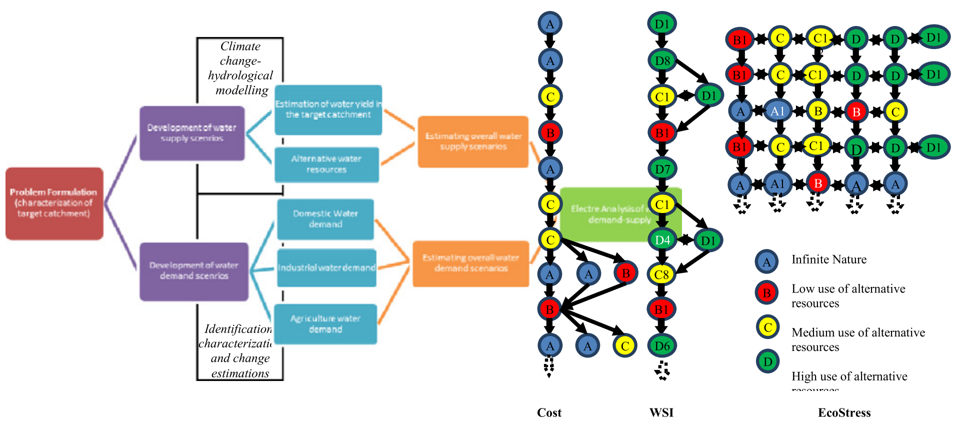
HIGHLIGHTS

- Water demand and supply scenarios analysis for water stressed industrial area.
- Application of outranking method for evaluating sectoral water allocation policies.
- Projection of long term (2011-2100) water demand and supply.
- Demand side drivers have a stronger impact on water management than supply-side factors.

GRAPHICAL ABSTRACT



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ABSTRACT

The regional water allocation planning is one of those complex decision problems where holistic approach to water supply management considering different criteria would be valuable. However, multi-criteria decision making with diverse indicators measured on different scales and uncertainty levels is difficult to solve. Objective of this paper is to develop scenarios for the future imbalances in water supply and demand for a water stressed Mediterranean area of Northern Spain (Tarragona) and to test the applicability and suitability of an outranking method ELECTRE-III-H for evaluating sectoral water allocation policies. This study is focused on the use of alternative water supply scenarios to fulfil the demand of water from three major sectors: domestic, industrial and agricultural. A detail scenario planning for regional water demand and supply has been discussed. For each future scenario of climate change, the goal is to obtain a ranking of a set of possible actions with regards to different types of indicators (costs, water stress and environmental impact). The analytical method used is based on outranking models for decision aid with hierarchical structures of criteria and ranking alternatives using partial preorders based on pairwise preference relations. We compare several adaptation measures including alternative water sources (reclaimed water and desalination); inter basin water transfer and sectoral demand management coming from industry, agriculture and domestic sectors and tested the sustainability of management actions for different climate change scenarios. Results have shown use of alternative water resources as the most reliable alternative with medium reclaimed water reuse in industry and agriculture and low to medium use of desalination water in domestic and industrial sectors as the best alternative. The proposed method has several advantages

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such as the management of heterogeneous scales of measurement without requiring any artificial transformation and the management of uncertainty by means of comparisons at a qualitative level in terms of the decision maker preferences.

1. Introduction

Sustainability of water resources is a concept that concerns all levels of planning and management, from local to global agendas. Management of water resources is a complex interplay between natural and human systems, driven by forces such as climatic, demographic, economic, social, institutional, political, and technological factors (Folke et al., 2007; UNEP, 2011; DOI, 2012). In recent years, climate has been the main driver of water resource management as droughts have dramatically increased in number and impact and the concerns about drought and water scarcity have grown in every part of the world (UN-Water, 2010; EC, 2012). In Europe, wide spread drought in 2003 and recent drought events of 2011 and 2012 in large parts of Southern Europe have been recognised as some of the worst drought of recent time with rainfall as low as 40% of normal (EC, 2012). In all the recent drought events (2003, 2011 and 2012) water availability was significantly reduced in the spring and water use restrictions were put in place in large parts of the EU. Recent communication of European Commission addressing the challenges of water scarcity and droughts in the European Union envisages that water scarcity and drought management can be handled through the Water Framework Directive (EC, 2007, 2012). It places a strong emphasis on demand side action as a measure to alleviate water scarcity, and to improve resilience against the consequences of drought. Supply augmentation may also require several years of planning and large capital investments before the water is available. In response to these challenges, governments are developing strategies to promote water conservation, water efficiency and alternate water resources. State led water allocation uses sectoral and intersectoral allocation of water, as the state usually is the only institution that has jurisdiction over all sectors of the economy. However allocations of water are followed with multiple objectives other than economic efficiency, such as equity and environmental protection. With increasing water scarcity, effective water allocation requires efficient water allocation systems. Efficiency requires that the water consumers and other stakeholders are involved in decision making, and prioritise water users for alternate water resources, since only this provides a true incentive to avoid conflicts. Each of these groups of stakeholders is concerned about different issues regarding alternate water resources. This poses major social, economic and environmental challenges. These will only be addressed when stakeholders are involved in decision making and effective ways can be found to allocate water between competing needs within a catchment, while sufficient water is retained to ensure the continuation of ecosystem functions.

Scenario planning is a well-established process in the water demand and supply management (Gallopín and Rijsberman, 2000; Alcamo and Gallopín, 2009; Haasnoot and Middelkoop, 2012). A scenario planning process can be used to guide the development of scenarios that provide a broad range of projections of future water demand and supply. In combination with future projection, a set of well-constructed scenarios representing a range of plausible future can assist in the assessment of future risks and the development of mitigation and adaptation options and strategies. However, ranking a large set of scenarios evaluated on multiple conflicting criteria is not a trivial task. Management actions planned with respect to one objective (e.g. water allocation) should minimise the conflicting and maximise the synergistic effect with respect to other management objectives (e.g. ecological status, water quality) (Kumar et al., 2013). Similarly, integration of diverse indicators measured on different scales and with different levels of uncertainty, must be considered in the planning processes. Multi-criteria decision making provides an opportunity to make management more efficient with more synergy and less conflict (Holzkaemper et al., 2012) and to identify new and innovative solutions that make management more sustainable (Pascual, 2007). However, complexities of multi-criteria decision making with diverse indicators measured on different scales and with different levels of uncertainty are well known (Lerner et al., 2011). To address these problems, a new generation of methods based on building outranking relations by pairwise comparison has been attracting the attention in the environmental domain (Arondel and Girando, 2000; Cavallaro, 2010; Khalili and Duecker, 2013). The outranking approach has several advantages such as the management of heterogeneous scales of measurement without requiring any artificial transformation and the management of uncertainty by means of comparisons at a qualitative level in terms of the decision maker preferences (Del Vasto-Terrientes et al., in press). Moreover, the result given to the decision maker is not a numerical score but a model of the preference relations between the different objects studied (i.e. alternatives, actions) when taking into account all the data in an integrated way.

This work is focused on the study of water demand and supply management of a highly industrialised small catchment of the Francolí River in the Mediterranean area of northern Spain of Catalonia. Most of the Mediterranean basins are characterized by high interannual and seasonal variability with long and intense dry periods (Nicault et al., 2008) and extreme rainfall and floods (Beguería et al., 2009). With some recent drought events (2007–2008), concerns regarding the reliability of the Catalan River basin system to meet future needs are even more apparent today. Many coastal areas with acute water shortage include some of the fastest growing urban and industrial areas of Europe as is the case of Catalonia in the Northern Spain (Terrado et al., 2014). At the same time, the effects of climate change and variability on the basin water supply are extreme and have been the focus of many scientific studies projecting a decline in the future yield of Catalan river basins (Delgado et al., 2010; Bangash et al., 2012; Sánchez-Canales et al., 2012; Marques et al., 2013; Terrado et al., 2014). Increasing demand, coupled with decreasing supplies, will certainly exacerbate the water imbalances of these acutely water stressed area. The purpose of this study is to develop scenarios for the future imbalances in water supply and demand in the study area over the next 90 years (through 2100), and to develop and analyse adaptation and mitigation strategies to resolve those imbalances. Due to the shortfall in supply from primary water resources, this study is focused on the use of alternative water supply scenarios for the demand of water of three major sectors: domestic, industrial and agricultural. For each future scenario of climate change, the goal is to obtain a ranking of a set of possible actions with regard to different types of indicators, such as costs, environmental impact, and water stress. The study contains four major phases to accomplish this goal: Water Supply Scenarios, Water Demand Scenarios, Development and Evaluation of Options and Strategies for Balancing Supply and Demand. The final step of this study is to rank different water supply strategies for possible demand scenarios using Electre-III-H outraking method.

2. Case study and problem description

Francolí River in the Mediterranean area of northern Spain is about 85 km in length, and including main tributaries is 109 km, constituting approximately a basin of 855 km^2 and covering the needs of a population of approximately 190,000 inhabitants (IDESCAT, 2011). The mainstream flows from Espluga de Francolí (Conca de Barbera) through