



An online platform supporting the analysis of water adaptation measures in the Alps

Dragana Bojovic, Carlo Giupponi, Hermann Klug, Lucia Morper-Busch, George Cojocar, & Richard Schörghofer

To cite this article: Dragana Bojovic, Carlo Giupponi, Hermann Klug, Lucia Morper-Busch, George Cojocar & Richard Schörghofer (2017): An online platform supporting the analysis of water adaptation measures in the Alps, Journal of Environmental Planning and Management, DOI: [10.1080/09640568.2017.1301251](https://doi.org/10.1080/09640568.2017.1301251)

To link to this article: <http://dx.doi.org/10.1080/09640568.2017.1301251>



© 2017 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group



Published online: 11 Apr 2017.



Submit your article to this journal [↗](#)



View related articles [↗](#)



View Crossmark data [↗](#)



An online platform supporting the analysis of water adaptation measures in the Alps

Dragana Bojovic^{a,b,*}, Carlo Giupponi^{a,b}, Hermann Klug^c, Lucia Morper-Busch^c,
George Cojocar^d and Richard Schörghofer^c

^aVenice Centre for Climate Studies (VICCS), Department of Economics, Ca' Foscari University of Venice, Italy; ^bEuro-Mediterranean Centre on Climate Change (CMCC), Venice, Italy; ^cInterfaculty Department of Geoinformatics (Z_GIS), University of Salzburg, Salzburg, Austria; ^dTIAMASG Foundation, Bucharest, Romania

(Received 23 February 2016; final version received 21 February 2017)

Climate change may result in reduced water supply from the Alps – an important water resource for Europe. This paper presents a multilingual platform that combines spatial and multi-criteria decision-support tools to facilitate stakeholder collaboration in the analysis of water management adaptation options. The platform has an interactive map interface that allows participants to select a location of their interest within the Alpine Arc. By utilising the decision-support tool, stakeholders can identify suitable adaptation solutions for different geographical units, according to their experience and preference. The platform was used to involve experts across Alpine borders, domains and decision-making levels, as well as a group of university students. The experts favoured the planning instruments for saving water, while the students inclined towards the measures that would improve water conservation. The initial results confirmed the suitability of the platform for future involvement of decision-makers in spatio-temporal analyses of adaptation pathways in the Alps.

Keywords: climate change; eParticipation; multi-criteria analysis; WebGIS; water scarcity

1. Introduction

The Alps are the water tower of Europe, greatly influencing the hydrological regime of the central European region (European Environment Agency 2009). Due to their natural abundance of water, the Alps have an impact on the water supply of major European rivers such as the Danube, the Rhine, the Rhone and the Po (Alpine Convention 2009). With its high orographic, topographic and climatological complexity, the Alpine area is more pronouncedly affected by climate change than are other regions within Europe (Bogataj 2007; Zimmermann *et al.* 2013). Regional adaptation activities should be identified and tailored to specific regional vulnerabilities (Rannow *et al.* 2010; Thieken *et al.* 2014), emphasising the spatial component of climate change adaptation (Eikelboom and Janssen 2015). The impacts of climate change in the Alps have been discovered to be unevenly distributed in space and time, e.g. annual increases in precipitation are expected in the north-western Alps while decreasing trends are expected in the south-eastern Alps (Schär *et al.* 2004; Auer *et al.* 2007; Norbiato *et al.* 2007; Beniston 2012). Furthermore, loss in glacier mass volume, permafrost melting and decreasing snow cover may reduce

*Corresponding author. Email: dragana.bojovic@cmcc.it

© 2017 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group

This is an Open Access article distributed under the terms of the Creative Commons Attribution-NonCommercial-NoDerivatives License (<http://creativecommons.org/licenses/by-nc-nd/4.0/>), which permits non-commercial re-use, distribution, and reproduction in any medium, provided the original work is properly cited, and is not altered, transformed, or built upon in any way.

summer discharge and reduce water availability in downstream regions dependent on the water supply from the Alps (Paul, Käab, and Haerberli 2007; Steger *et al.* 2013; Ruiz-Villanueva *et al.* 2015). All these factors may result in the Alps and the surrounding region experiencing a higher frequency of drought periods in the summer (Briffa, van der Schrier, and Jones 2009; Espon 2010), as well as other extreme impacts such as debris flows, landslides, disturbance in flora and fauna distribution and biodiversity loss (Klug, Schörghofer, and Reichel 2014; Stagl, Hattermann, and Vohland, 2015).

Notwithstanding the current abundance of water in the area, the importance of the Alpine water resources for water provision, energy production and tourism in Europe, together with the pronounced susceptibility of the Alps to climate change, makes the water sector a top priority when considering adaptation to climate change in the Alps (Beniston, Stoffel, and Hill, 2011). The future of Alpine water resources is relevant for large parts of European society (Gobiet *et al.* 2014) and the Alpine Convention (2009) has recognised the importance of including a broader group of stakeholders in discussions about water management in the Alps.

This paper presents an online platform as a component of the eParticipation approach developed within the C3 Alps research project aimed at enabling collaboration amongst a broader stakeholder group in analysing alternative adaptation measures for water management in the Alps. As discussed in Klug, Schörghofer, and Reichel (2014), previous Alpine Space Programme projects and initiatives on adaptation to climate change in the Alps have been synthesised, transferred and implemented in an adaptation knowledge inventory portal. The success of adaptation measures relies on local knowledge and activities, but also on the acceptance of these measures by the public in order to ensure their effectiveness (Lopez-Marrero 2010). Achieving meaningful participation is thus a laudable goal for climate change adaptation (Lyle 2015; Tompkins *et al.* 2010). The project involved stakeholders in different ways, including through the dissemination of findings, the organisation of events and eParticipation in the form of online surveying and collaboration on problem-analysis and solution-finding, in order to support bottom-up adaptation measures in the Alpine regions and municipalities.

In the C3 Alps project, eParticipation first involved stakeholders through an online questionnaire aimed at analysing the information needs and communication habits of the project's target groups. The results of the questionnaire revealed the strong interests of stakeholders in visualised and geospatial information such as maps and graphs (Bojovic, Pfefferkorn, and Thamm 2013). The presentation of spatial information through web tools depends upon, and should be shaped by, the user community and their information needs (Mittlböck *et al.* 2012; Klug and Kmoch 2014). The results of the survey were therefore an important stimulus for integrating interactive maps in the subsequent phase of eParticipation. In addition, previous studies have proved maps to be useful in providing an interface between tools and end-users (Malczewski 2006; Arciniegas, Janssen, and Rietveld 2013). In the second phase, eParticipation was used to empower stakeholders to participate in the analysis of alternative adaptation measures and suitable solutions using the online participatory platform, described herein, in which a Web Map Viewer and a multi-criteria decision-support component were integrated.

As a recognised aspect of cross-sectoral importance in the Alps, water management was a key focus of this participatory exercise. More specifically, we analysed the adaptation of the Alps to expected future water scarcity as an area in which the behaviour of every individual is of particular significance (Hohenwallner, Saulnier, and Brancelj 2011; Hohenwallner, Saulnier, and Castaings 2011; Klug *et al.* 2012). The aim of this study was to contribute towards increasing the diversity of the audience and the numbers

of participants involved in project activities. The usability of this stakeholder-tailored, Pan-Alpine interactive web platform was tested. We explored the contribution of the multilingual interface using a multi-scale level approach (from regional to local), as well as the availability of a broad project partnership network for the platform distribution to the success of such an approach. We further wanted to understand the preferences and needs of different stakeholders regarding climate change adaptation measures in the Alps. Accordingly, the emphasis was not placed on finding a final solution for adaptation throughout the Alps but on exploring various interpretations of alternative possibilities. Finally, we wanted to understand whether such an approach – merging eParticipation, multi-criteria analysis (MCA) and spatial tools – could be used in the future for climate change adaptation planning. This paper presents the online platform and the initial results collected through eParticipation from stakeholders across the Alps, students from Venice and stakeholders from the local case study in Val Brenta in Italy.

2. Methodology

2.1. The online platform for participation in the analysis of adaptation measures

The C3 Alps Online platform comprises two main components: (1) a decision-support system (DSS) component providing MCA methods to analyse and rank a predefined set of adaptation options; and (2) a web mapping application that presents and compares preferred adaptation options in specific locations within the Alpine Space. Both components are further developments of pre-existing toolboxes. MCA functionalities are provided by the web-based version of the mDSS software (Giupponi 2007), i.e. mDSSweb (Bojovic *et al.* 2015; Bonzanigo *et al.* 2015), providing a simplified interface to involve stakeholders in the analysis of alternative options in decision-making related to environmental issues. In the current platform, mDSSweb guides users through the elicitation and sharing of their preferences and expectations regarding a set of climate change adaptation measures identified by the project consortium as being of specific interest in the field of water resource management and climate change.

The Web Map Viewer is an interactive open source and standards-based web mapping application using OpenLayers mapping functionality, ExtJS for the Graphical User Interface and the charts, and Google Maps as the base map. The Web Map Viewer provides the routines for geo-location, spatial browsing and querying, as well as the display of results. The viewer is thus both the starting interface with which the user is prompted and the tool for visualising the spatial distribution of the results.

An important feature of the platform is its multilingual interface that allows users to select the preferred language while the elaboration routines to combine and process data provided by the users work independently of linguistic choices. English, German, Italian and Slovenian interfaces have been implemented.

Having selected their preferred language, users are guided to provide personal details for identification and to select a location as a reference location by geo-tagging, i.e. clicking on the specific location to which the user wants to refer the evaluation exercise (Figure 1). The user is next redirected to the mDSSweb component, which is given in four steps.

2.2. Exercise design in mDSSweb

The first step of the mDSSweb approach briefly explains the exercise and introduces the evaluation criteria, allowing the user to go into the details of the structure of the

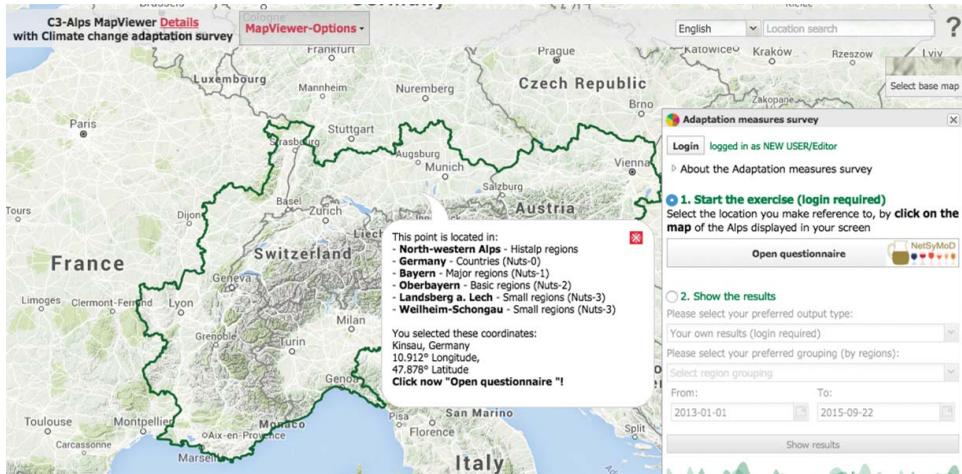


Figure 1. Map Viewer – the beginning of the exercise.

evaluation exercise. As for the adaptation measures, the evaluation criteria were agreed within the project consortium on the basis of previous experiences in the field (Florke *et al.* 2011) and were selected to provide a comprehensive set of decision dimensions that every stakeholder or decision maker may consider when approaching the analysis of the issues in question. The following criteria were adopted:

- (1) Effectiveness – the extent to which the adaptation measures directly contribute to reducing the system’s vulnerability to the expected impacts of climate change.
- (2) Efficiency – the characteristic of measures that bring higher benefits in comparison to their costs of implementation, including transaction and monitoring costs.
- (3) Environmental performance – the potential contribution of a measure to improving or protecting the state of the environment, for example by contributing to the conservation of natural habitats, natural resources and ecosystem services.
- (4) Side-effects – the unintended outcomes, both positive and negative, of the adaptation measures, going beyond their specific scope: e.g. their positive effects on employment or negative effects on different environmental aspects.
- (5) Contribution to the resolution of conflicts – the potential contribution of a measure to limit existing conflicts, for instance conflicts between different sectors competing for the same water resource.
- (6) Performance under uncertainty – the capability of the measures to maintain their performance under a wide range of uncertain future changes in climatic and socio-economic conditions. Measures that meet this requirement may be either robust in response to uncertainties or flexible in design and implementation.

The second mDSSweb step presents the alternative adaptation measures and enables stakeholders to evaluate these measures against the set of criteria. This exercise analysed alternative measures that can help adapt to water scarcity resulting from climate change. The following set of climate change adaptation measures from the field of water resources management was identified:

- (1) Improving water infrastructure and reducing leakage, thus saving water by controlling and limiting water leakage from inefficient and/or ageing municipal

and agricultural water distribution systems. This is an engineering-based measure.

- (2) Improving water efficiency and conservation in households and hotels, thus reducing water wastage by reducing the water consumption of households and hotels. This measure involves choosing more water-efficient devices, products and practices. It may be supported by specific codes, protocols and certifications, and in extreme cases (drought periods) it may include restrictions and rationing that may temporarily limit certain uses of water, for example the irrigation of lawns and car washing. This is a set of voluntary and behavioural measures.
- (3) Introducing wastewater treatment and reuse, involving the reuse of domestic water from baths, showers and sinks (grey water) for toilet flushing and gardens. The grey water from households and hotels could also be reused in agriculture, e.g. for irrigation, and for industrial processes., e.g. cooling. This measure reduces overall demand for water, thereby easing pressure on available water. This is a combination of technological and management measures.
- (4) Undertaking awareness-raising campaigns and promoting behavioural changes (focusing on tourists), involving campaigns for promoting awareness of the impacts of climate change on water availability and the active role that tourists can play in reducing the negative consequences of water use. Public awareness is important in order to increase enthusiasm and support, stimulate self-mobilisation and action, and to mobilise local knowledge and resources. Tourists are informed about simple water-saving actions they can take in their daily routines. This behavioural measure can be combined with other technology or management options.
- (5) Improving planning instruments for water saving, thus protecting water resources through planning instruments that reduce the water requirements of targeted sectors and enable the optimal use of available water resources. These planning instruments include zoning, financial incentives and disincentives, regulatory measures, market-based instruments, strategic planning for catchment and resource management, including water use for artificial snow. This alternative includes a catalogue of measures to be implemented through planning instruments and legislation.

The qualitative evaluation of alternative measures is performed through an analysis matrix (AM) interface, with measures specified across the columns and the evaluation criteria in the rows. The user provides values for each cell of the matrix to express expectations about the performance of each alternative measure for every evaluation criterion. The proposed value ranges from 1 (very low performance) to 5 (very high performance).

As a third step, users weight criteria according to their relative importance. The weights are allocated through a graphical interface and then calculated with the revised Simos procedure, according to Figueira and Roy (2002) (Figure 2). The interface

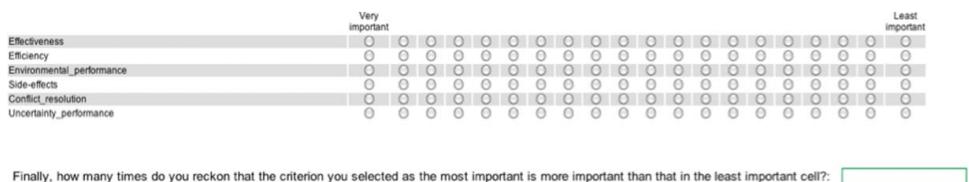


Figure 2. Criteria-weighting with the revised Simos interface developed for mDSSweb.

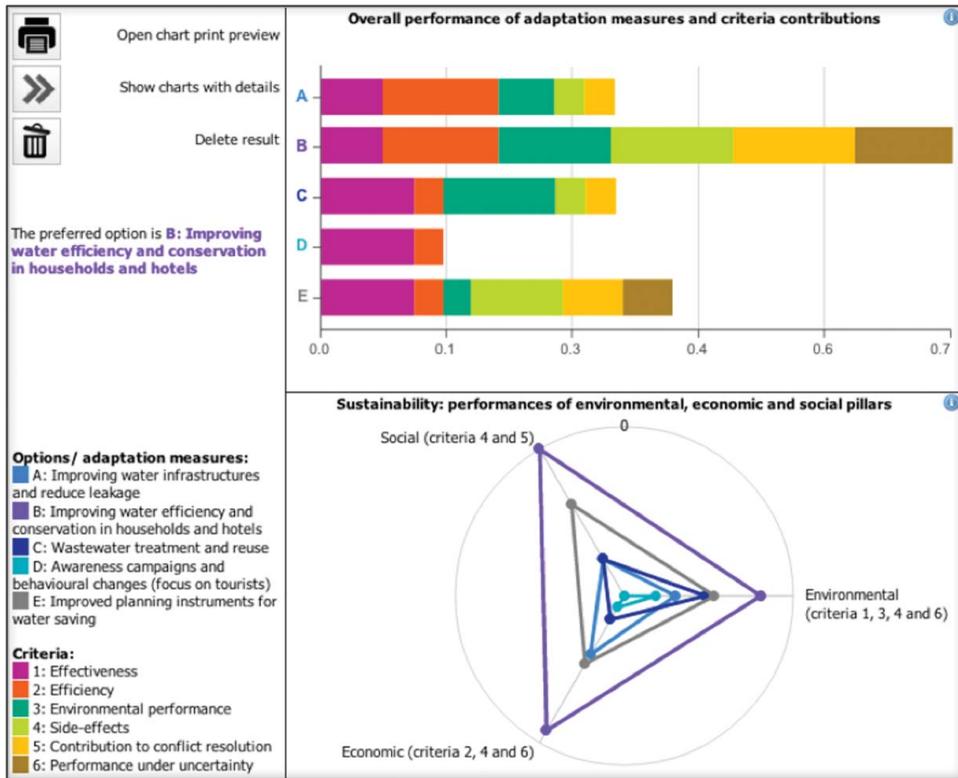


Figure 3. Visualisation of individual evaluation results. Overall performance of adaptation measures and criteria contribution are presented in the upper chart, the values, ranging from 0 to 1 appear on mouseover. Sustainability performance is presented in the lower chart, the winning option B fulfils the social dimensions better than economic and environmental dimensions, while option C has the best environmental performance. (See online colour version for full interpretation).

developed for the mDSSweb platform permits participants to rank criteria along a scale of relevance. This ensures a hierarchical arrangement of criteria in a visual way (Bojovic *et al.* 2015).

Using MCA evaluation techniques, alternative options are evaluated against their performance by applying aggregation algorithms to the set of values stored in the AM and in the criteria weight vector. mDSSweb adopted the simple additive weighting (SAW) algorithm, which calculates the final score for each adaptation option with the sum of the criterion values, weighted by the vector of weights (Giupponi *et al.* 2006) (Figure 3). SAW is considered one of the simplest MCA methods, mirroring the main concept of multi-criteria evaluation paradigm: the integration of the criteria values and weights into a single measure. Limitations of this method include that all the criteria need to be maximising and their values positive. In addition, other MCA methods, such as PROMETHEE (Brans 1982; Brans and Vincke 1985) and ELECTRE (Roy 1978), can capture additional properties, such as preference functions for different criteria that can help by incorporating uncertainties, common for any valuation approach. The precise characteristic of SAW that it does not ask for any additional inputs from participants, however, made it most convenient for online use by a broad audience with different

background knowledge (Bojovic *et al.* 2015).

$$\Phi_{\text{SAW}}(a_i) = \sum_{j=1}^n w_j \times u_{ij} \quad (1)$$

where a is an alternative adaptation measure, w is a weight of criterion j and u is performance of the measure a_i against the criterion j .

In the final group decision-making step, all individual rankings are combined as a voting procedure for calculating an overall ranking of the alternatives. mDSSweb applied the Borda rule to calculate an overall score by combining all the individual rankings of the alternative measures. The Borda rule attaches a number of points to each option equal to the number of options ranked lower than it, so that an option receives $n - 1$ points when it is ranked first, $n - 2$ when it is second, until the last option which receives zero points, where n is the number of options (Young 1974).

2.3. Presentation of results

The fourth step of mDSSweb consists of the implementation of the MCA algorithm and storing the calculated results in the database. Users can visually explore both individual and regionally aggregated results through the Web Map Viewer by clicking on the respective point or area. The presentation of individual results has been executed through the following graphs:

- Overall performance of adaptation measures and criteria contributions – the SAW results are visualised in a histogram. The length of the bars is proportional to the scores and the colour segments show how the weighted performances of each criterion contribute to the overall performance of a measure (Figure 3).
- Sustainability performance – the performance of each measure is balanced according to the three dimensions of sustainability: economic, environmental and social. These performances are presented in a triangular chart in which scores are calculated for each dimension by assigning the criteria values to one or more sustainability pillars. Ideally, options should be presented as equivalent triangles. Alternatively, they denote the fact that the three dimensions are not balanced (Figure 3).
- Evaluation of the options against the criteria – a polar graph shows how the adaptation options perform according to the criteria considered before weighting (Figure 4). Polygons with vertices closer to the centre of the chart denote poor performance while vertices close to the external rings show good performance. A regular polygon shape shows balanced criteria performance while irregular shapes denote notable differences between the criteria adopted.
- Relative importance of criteria – a pie chart shows the relative importance (weight) assigned to each of the criteria (Figure 4). These weights are used to calculate the final score, i.e. overall performance and sustainability performance.

The individual results are tagged to the corresponding locations on the map of the Alps provided by the Web Map Viewer. This allows for regional analysis of the results. Individual results are combined in a summary screen showing a synthesis of all the collected contributions.

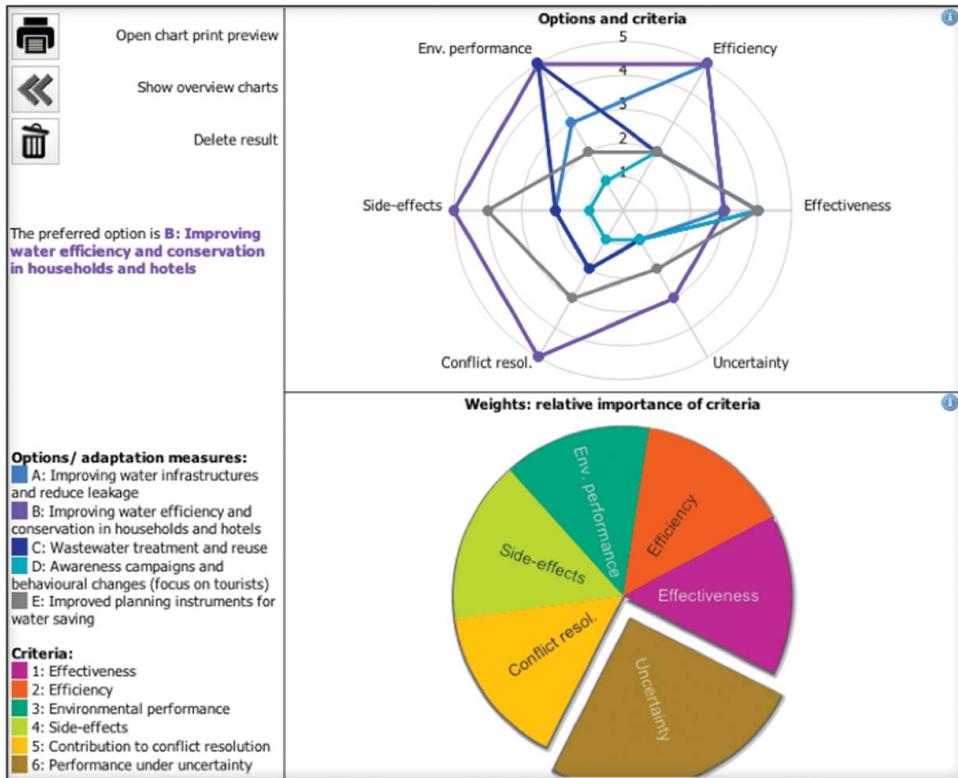


Figure 4. Visualisation of individual evaluation results: evaluation of the options against the criteria: (upper chart) before criteria weighting; (lower chart) criteria weighting. The platform users could see the values in the pie chart on mouseover. (See online colour version for full interpretation).

Aggregated results explore assessments made by all participants. Graphical and geographical displays show aggregated preferences by sub-groups and by spatial distribution, i.e. the overall result of participants in individual geographical regions, which can refer to a country or smaller regions – using the official EU Nomenclature of Territorial Units for Statistics (NUTS).

2.4. Tailoring the online platform to case study areas

In addition to targeting the audience throughout the Alps, the exercise was applied to a specific case study in the Brenta Valley (Val Brenta) in north-east Italy. The Brenta River basin is a catchment within the Veneto Region and the Autonomous Province of Trento, characterised by regulation for hydroelectric power and irrigation purposes. In order to test the feasibility of tailoring the generic set of adaptation options to local challenges, characterising the geographical, economic, social and cultural diversity of the Alps, the same set of measures described above was discussed with local stakeholders and re-phrased and implemented in a separate component of the online platform. The general discourse about emerging water scarcity challenges in the Alps was tailored to the specific case of Val Brenta and the ongoing debate about water management strategies was incorporated. This case presents an example of how the platform can be used for setting up local climate change adaptation measures.

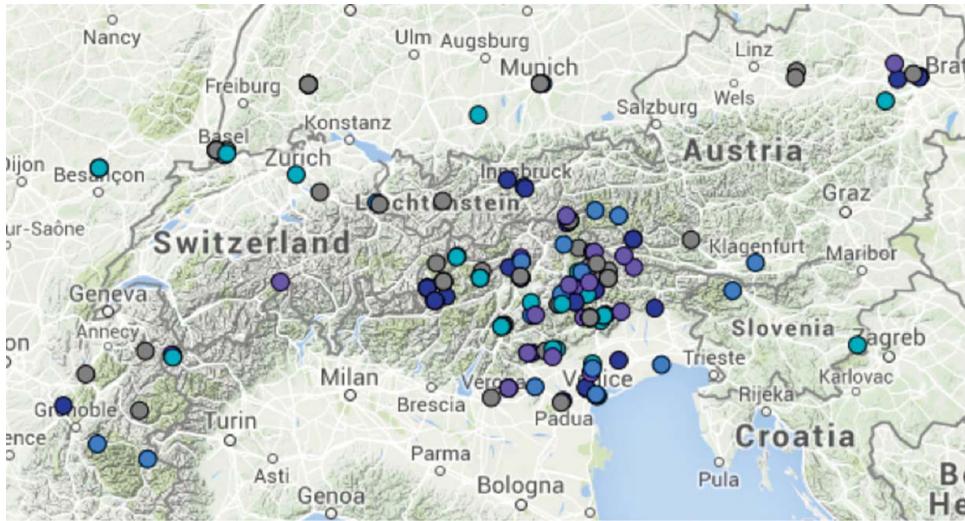


Figure 5. Locations selected by participants. Dot colour corresponds to the preferred alternative (A–E). Dot location corresponds to the location selected by the participant.

3. Results

The announcement of the Alpine exercise was distributed amongst Alpine Space Programme project partners using mailing lists and online networks, such as networks of newsletter subscribers, e.g. Cipra's alpMEDIA newsletter and the Austrian Climate Alliance Newsletter. Results were obtained from 45 stakeholders spread throughout the Alpine area. Graduate and undergraduate students from the Ca'Foscari University of Venice were also involved in the testing of the platform and we present here results obtained from 100 students attending the undergraduate programme in Environmental Sciences. Figure 5 shows the locations for which input to the online exercise was provided, clearly demonstrating a high concentration of participants in north-eastern Italy, which corresponds mainly to the fieldwork by the students.

Participants evaluated the alternative adaptation measures and the individual results were produced applying the MCA approach described above. Using the Borda decision rule, an overall ranking of the alternatives, resulting from selected groups or even the whole data-set, was received. Looking into the results obtained from the stakeholders and the university students, some differences can be observed (Figure 6). Specifically, a strong preference for option E, i.e. improving planning

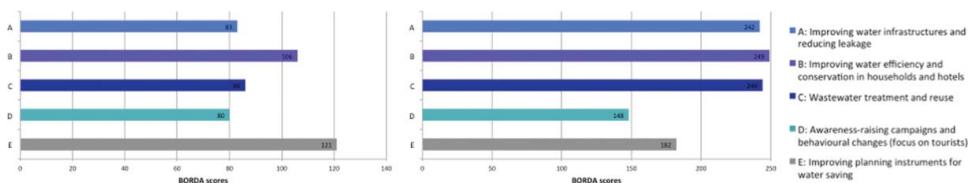


Figure 6. The overall results obtained from stakeholders from the Alps (left) and from university students (right). Measures are presented on the Y axis and Borda scores on the X axis. (See online colour version for full interpretation).

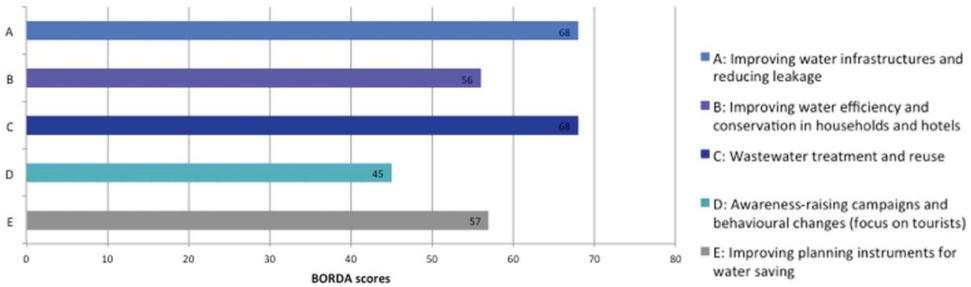


Figure 7. The overall results from the Val Brenta exercise. Measures are presented on the Y axis and Borda scores on the X axis. (See online colour version for full interpretation).

instruments for water saving, is observed among the stakeholders from the Alps, while the students demonstrated a slight preference for option B, i.e. improving water efficiency and conservation in households and hotels, an option which was scored second by the stakeholder sub-group. Interestingly, within the stakeholder group, 45% of those who selected measure E as a preferable option are from the academic sector. Then again, 50% of the small proportion that selected option D, i. e. awareness campaigns and behavioural change, as a preferable measure are from the private sector.

The Val Brenta exercise was distributed among a narrow group of selected stakeholders interested in this particular case and obtained 27 answers. Evaluating the same five measures, tailored for the Val Brenta setting, a compromise overall solution shows the highest score for option A, i.e. improving water infrastructures and reducing leakage, and option C, i.e. wastewater treatment and reuse (Figure 7).

The overall criteria weighting was similar in the three groups (Figure 8). However, the general stakeholders group, as well as the group from Val Brenta, gave preference to the criterion of effectiveness, while according to the students, environmental performance is the most important criterion.

The general sustainability performance of the evaluated measures in the exercise was almost uniform across the three groups of participants (Figure 9). The environmental pillar was assigned the greatest importance, followed by the economic pillar. The student group assigned more importance to the social pillar than did the other two groups.

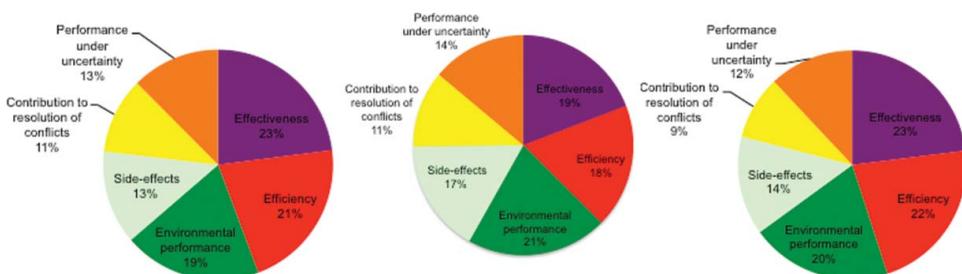


Figure 8. The overall criteria weights; general stakeholders from the Alps (left), students (middle), Val Brenta stakeholders (right). (See online colour version for full interpretation).

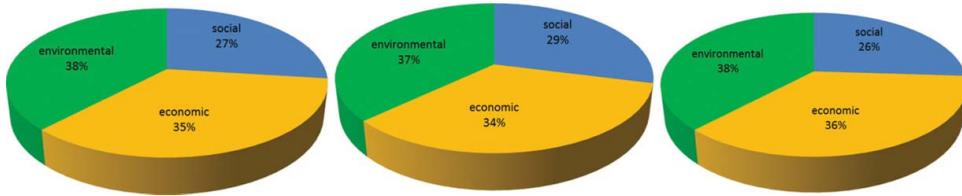


Figure 9. General sustainability performance of the evaluated measures; general stakeholder group from the Alps (left), university students (middle), stakeholders from Val Brenta (right). (See online colour version for full interpretation).

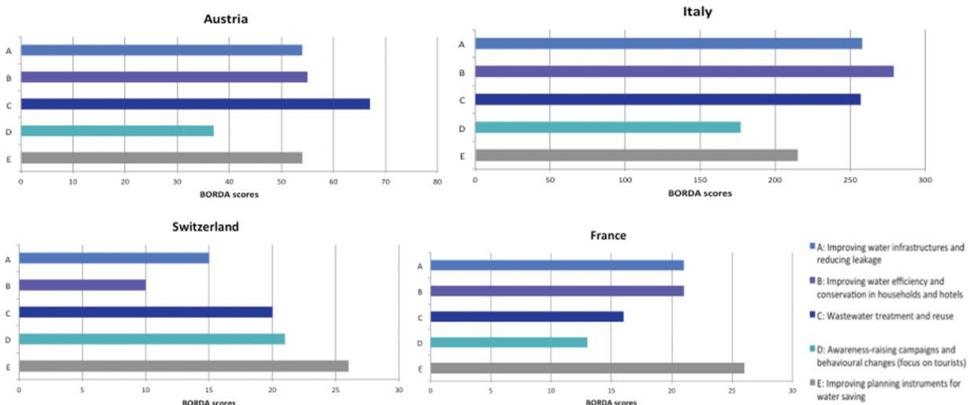


Figure 10. Overall results in different Alpine countries. Measures are presented on the Y axis and Borda scores on the X axis. (See online colour version for full interpretation).

Stakeholders from the Alps most frequently used the English language while participating in the exercise, while students, as well as stakeholders from Val Brenta, used the Italian interface.

Analysing results from different sub-groups of participants determined by geographical location we found that, in the case of the country level, there is a steady dominance of option E, i.e. improving planning instruments, in the sub-groups from France and Switzerland. The preferable alternative for the stakeholders from Austria was option C, i.e. wastewater treatment and water reuse, while the group from Italy, with most of the results coming from students, gave the highest score to option B, i.e. improving water efficiency and conservation in households and hotels (Figure 10).

4. Discussion

Acknowledging the strong interest of stakeholders in visualised and geospatial information such as maps and graphs, as revealed in the first eParticipation phase of the C3 Alps project, we linked an MCA with a Web Map Viewer. This formed a prototype analysis and communication platform, which, if adopted by a competent administration, may evolve in the future into an online participatory decision-support tool. The online platform allows single users to carry out an evaluation exercise, having automated calculation of results that appear in maps and graphs in real time. The graphical

presentation of individual results is available immediately after completing the exercise. The same is true for the option to explore graphical and geographical results of groups from different regions or of the whole set of non-personalised users' preferences. Even without taking part in the exercise, users can at any time consult the platform to explore the status of the stakeholder consultation. The platform organisers can also periodically download the data-set of results and conduct more in-depth analyses, such as for example the evolution of preferences over time.

With an available Internet connection, participants could take part in the online exercise at any time convenient to them. Moreover, there was also no spatial limitation to interested users who could participate from any geographical location throughout the Alpine Arc and beyond. The availability of the platform and the proposed exercise were advertised amongst a broad network of Alpine stakeholders through mailing lists and newsletters. Nevertheless, the number of responses was modest. Looking into the participants' comments provided in the exercise we could not detect a specific barrier to participation once a user started the exercise. This indicates that a lack of motivation to participate in this topic or this type of exercise might have hindered widespread participation. This is a typical challenge in any participatory exercise running in parallel to other 'more urgent' decision-making processes. Another limiting factor could be related to technical problems which affected the platform in its initial version, in particular affecting the functioning of the login procedure with different Internet browsers, versions and operating systems. Most of these problems resulted from the use of old web browsers incompatible with the state-of-the-art web techniques applied in the platform. Drawing also from our previous experience with similar tools (see Bojovic *et al.* 2015), we concluded that the low response-rate could be a result of the trade-off made between the complexity and comprehensiveness of a system and the simplicity of its use, all this in view of the lack of motivation on the part of potential users. The exercise that focused on the particular case study in Val Brenta had a higher response-rate within its narrow group of motivated and active local stakeholders. This could indicate that framing the issue in the local context, unlike the more general topic of climate change and water resources in the Alps, could add more concreteness to the exercise and raise more interest amongst stakeholders.

The multi-level character of the exercise meant that the tool was able to be applied at different scales throughout the Alps, from regional to local level, while the platform also enabled the presentation and exploration of results from different NUTS levels. This feature also ensures the transferability of the approach to other regions or domains of interest. Indeed, a pilot case has already been conducted to evaluate alternative solutions for local forestry planning in Val Boite.

The results from the general stakeholder sample show a high preference for the option that would improve planning instruments for water saving. Having approached the participants through professional mailing lists, thematic online networks and newsletters, we assume that there was a significant percentage of experts amongst the participants who were familiar with the relevant policy, as well as other stakeholders interested in the topic of climate change and adaptation measures throughout the Alps. Forty-five percent of those that preferred this measure chose academia as the profession that characterised them best. According to the results from this group, efficiency and effectiveness are the most important criteria according to which the suitability of alternative adaptation measures should be estimated, followed by environmental performance. By contrast, the students from the Environmental Science programme demonstrated a slight preference for improving water efficiency and conservation. These potential future stakeholders assigned most importance to environmental performance as an evaluation criterion for

estimating the suitability of alternative adaptation measures. Focusing on local catchment challenges, such as intensive water abstraction for irrigation and hydropower production, the participants from Val Brenta considered the most suitable solutions to be those of improving water infrastructure and reducing system leakages, together with wastewater treatment and reuse. General stakeholders from the Alps and local stakeholders from Val Brenta are evidently more supportive of policy and technological measures, the performance of which should be evaluated primarily on the basis of their effectiveness. Then again, students believe that soft measures such as water conservation also provide results and that environmental performance is an important characteristic of adaptation measures. Undertaking awareness-raising campaigns and promoting behavioural changes by focusing on tourists was the alternative measure that scored significantly lower in all three main groups of participants. This demonstrates that users of the platform consider that more concrete measures are needed to address water scarcity throughout the Alps.

The preferences expressed by participants from various regions differed. The preference of the sub-group from France and Switzerland corresponded to the general preference for option E, i.e. improving planning instruments, while option C, i.e. wastewater treatment and water reuse, scored first for the participants from Austria. Participants from Italy, including the students from Venice, who comprised the biggest sub-group, preferred option B, i.e. improving water efficiency and conservation, which is a logical preference for the south-eastern Alps where an annual decrease in precipitation is expected (Auer *et al.* 2007). This result also confirms that the climate change adaptation measures are, and should be, tailored to the different impacts across the Alps and that not only one overall solution can be applied.

The language barrier has often been recognised as an obstacle for participation in online exercises (O'Neill and Boykoff 2011). The multilingual interface was aimed at overcoming the problem of the language barrier and allowing for the tool to be used throughout the Alpine Space and beyond. Nevertheless, most of the participants within the general stakeholder group opted to use the English interface. However, the multilingual interface proved useful for engaging local stakeholders from Val Brenta and the Italian students, both of which groups preferred to use the Italian interface of the platform. This indicates that although the English language can be sufficient when targeting only experts, the multilingual platform is of particular advantage for local stakeholders throughout the Alpine Arc.

5. Conclusions

The results show that a MCA decision-support platform can be integrated with web enabled geo-spatial tools in a Web Map Viewer, facilitating recognition of the participants' locations and providing geographical characterisations of the adaptation preferences. The results revealed how adaptation preferences differ across the regions of the Alpine Space, e.g. from south-east to north-west, as well as across different groups of users. Still, all participants showed a preference for more concrete adaptation measures while the option to undertake awareness campaigns scored lowest. Applied on different scales, the platform proved more efficient in raising participants' interest when tailored for local cases. The multilingual character of the platform proved useful for the cross-border Alpine Space, although the majority of experts from different countries opted to use the English interface when participating in the exercise.

In the future this eParticipation approach, merged with spatial and multi-criteria decision-support tools, could be redesigned to consider different options and to engage the broader public in discussions regarding climate change adaptation whenever concrete

issues open to question emerge and raise the interest of Alpine stakeholders. Such a platform could contribute to revealing needs and preferences in different regions and local settings. The platform can also be used for supporting specific local planning or decision processes and collecting spatial information in different contexts, as demonstrated in the case study of Val Brenta and Val Boite. Incorporating interactive maps and MCA, and providing immediate presentation of results, this platform provides an operational solution for eParticipation, which is more and more considered as a fundamental component of participatory processes. Ideally, but beyond the objectives of this work, robust scientific methods should then be implemented to provide quantitative assessment of the adaptation alternatives using the same assessment framework (alternatives and criteria). In this way science and technology, on the one side, and the general public, on the other, could efficiently and transparently provide policy-makers with all the elements needed for a sound decision. In such a context, the proposed methods and the tool for participation would be an important asset to a formal climate change decision-support process that would compare and combine experts' elicitation with information about public preferences in different locations and across various stakeholder groups.

Acknowledgement

This work was supported by the Alpine Space Programme, under the project "Capitalising Climate Change Knowledge for Adaptation in the Alpine Space" (C3-Alps, 9-3-3-AT), under the priority programme "Environment and Risk Prevention." We are grateful for the support provided by the C3 Alps project consortium, through valuable comments and suggestions. We would like to thank all the participants for their useful inputs and suggestions for the platform improvements and their input to the online exercise.

Disclosure statement

The authors declare that they have no competing interests.

Funding

This work was supported by the European Regional Development Fund through the Interreg Alpine Space programme [C3-Alps, 9-3-3-AT]. http://www.alpine-space.org/2007-2013/projects/projects/detail/C3-Alps/show/index.html#project_outputs.

References

- Alpine Convention. 2009. *Water and Water Management Issues: Report on the State of the Alps. Alpine Convention: Alpine Signals – Special Edition 2. Permanent Secretariat of the Alpine Convention*. Bolzano, Italy: Alpine Convention.
- Arciniegas, G., R. Janssen, and P. Rietveld. 2013. "Effectiveness of Collaborative Map-Based Decision Support Tools: Results of an Experiment." *Environmental Modelling and Software* 39: 159–175. doi: 10.1016/j.envsoft.2012.02.021.
- Auer I., R. Böhm, A. Jurkovic, L. Wolfgang, A. Orlik, R. Potzmann, W. Schoner *et al.* 2007. "HISTALP—Historical Instrumental Climatological Surface Time Series of the Greater Alpine Region." *International Journal of Climatology* 27 (1): 17–46. doi: 10.1002/joc.1377.
- Beniston, M., M. Stoffel, and M. Hill. 2011. "Impacts of Climatic Change on Water and Natural Hazards in the Alps: Can Current Water Governance Cope with Future Challenges? Examples from the European "ACQWA" Project." *Environmental Science and Policy* 14: 734–774. doi: 10.1016/j.envsci.2010.12.009.

- Beniston, M. 2012. "Impacts of Climatic Change on Water and Associated Economic Activities in the Swiss Alps." *Journal of Hydrology* 412–413: 291–296. doi: 10.1016/j.jhydrol.2010.06.046.
- Bogataj, L.K. 2007. "How Will the Alps Respond to Climate Change? Scenarios for the Future of Alpine Water." *Alpine Space – Man and Environment* 3: 43–51.
- Bojovic, D., W. Pfefferkorn, and U. Thamm. 2013. *Survey on Climate Change Adaptation: How to Inform Local, National and Regional Administration Successfully*. Deliverable of WP5 in the C3-Alps project. Internal project report. C3-Alps project.
- Bojovic, D., L. Bonzanigo, C. Giupponi, and A. Maziotis. 2015. "Online Participation in Climate Change Adaptation: A Case Study of Agricultural Adaptation Measures in Northern Italy." *Journal of Environmental Management* 157: 8–19. doi: 10.1016/j.jenvman.2015.04.001.
- Bonzanigo, L., D. Bojovic, C. Giupponi, and A. Maziotis. 2015. "From Exploration of Farmers' Autonomous Adaptation to the Design and Evaluation of Planned Interventions in the Veneto Region, Italy". *Regional Environmental Change* 10113: 1–14. doi: 10.1007/s10113-014-0750-5.
- Brans, J.P. 1982. "L'ingenierie de la decision. Elaboration d'instruments d'aide a la decision. Methode PROMETHEE" [Decision Making. Development of Decision-Making Tools. The PROMETHEE Method]. In *L'Aide a la Decision: Nature, Instruments et Perspectives d'Avenir* [Decision Support: Nature, Instruments, and Future Perspective], edited by R. Nadeau and M. Landry, 183–214. Quebec: Presses de Universite Laval.
- Brans, J.P., and Ph. Vincke. 1985. "A Preference Ranking Organization Method: (The PROMETHEE Method for Multiple Criteria Decision-Making)." *Management Science* 31 (6): 647–656.
- Briffa, K.R., G. van der Schrier, and P.D. Jones. 2009. "Wet and Dry Summers in Europe Since 1750: Evidence of Increasing Drought." *International Journal of Climatology* 29: 1894–1905
- European Environment Agency. 2009. *Regional Climate Change and Adaptation. The Alps Facing the Challenge of Changing Water Resources*. EEA Report No 8/2009. Copenhagen: European Environment Agency.
- Eikelboom, T., and R. Janssen. 2015. "Collaborative Use of Geodesign Tools to Support Decision-Making on Adaptation to Climate Change." *Mitigation and Adaptation Strategies for Global Change* 2015: 1–20. doi: 10.1007/s11027-015-9633-4.
- ESPON. 2010. *ESPON CLIMATE – Climate Change and Territorial Effects on Regions and Local Economies*. Applied Research Project 2013/1/4. Revised Interim Report, ESPON and TU Dortmund University. Luxembourg: ESPON.
- Figueira, J., and B. Roy. 2002. "Determining the Weights of Criteria in the ELECTRE Type Methods with a Revised Simos' Procedure." *Journal of Operational Research* 139: 317–326.
- Florke, M., F. Wimmer, C. Laaser, R. Vidaurre, J. Tröltzsch, T. Dworak, U. Stein, et al. 2011. *Climate Adaptation: Modelling Water Scenarios and Sectoral Impacts*. Annexes to the Final Report. Kassel: CESR. Accessed October 25 2015. http://climwatadapt.eu/sites/default/files/ClimWatAdapt_annex_final.pdf
- Giupponi, C., R. Camera, A. Fassio, and A. Lasut. 2006. *Network Analysis, Creative System Modelling and Decision Support: The NetSyMoD Approach*. Nota di Lavoro 46. Venice, Italy: FEEM.
- Giupponi, C. 2007. "Decision Support Systems for Implementing the European Water Framework Directive: The MULINO approach." *Environmental Modelling and Software* 22 (2): 248–258. doi: 10.1016/j.envsoft.2005.07.024.
- Gobiet, A., S. Kotlarski, M. Beniston, G. Heinrich, J. Rajczak, and M. Stoffel. 2014. "21st Century Climate Change in the European Alps: A Review." *Science of the Total Environment* 493: 1138–1151. doi: 10.1016/j.scitotenv.2013.07.050.
- Hohenwallner, D., G.M. Saulnier, and A. Brancelj. 2011. *Water Resources Management and Water Scarcity in the Alps: Recommendations for Water Resources Managers and Policy-makers. Interreg IVB, Alpine Space Programme, project 5-1-3-F*. Savoie: University of Savoie.
- Hohenwallner, D., G.M. Saulnier, and W. Castaings. 2011. *Water Management in a Changing Environment: Strategies Against Water Scarcity in the Alps. Project Outcomes and Recommendations. Interreg IVB, Alpine Space Programme, Project 5-1-3-F*. Savoie: University of Savoie.
- Klug, H., Z. Dabiri, B. Hochwimmer, P. Zalavari. 2012. "Assessing Drinking Water Consumption by Inhabitants and Tourists in the Alps Using a WebGIS for Information Distribution." *International Journal of Biodiversity Science, Ecosystem Services and Management* 8: 50–70. doi: 10.1080/21513732.2012.680499.

- Klug, H., and A. Kmoch. 2014. "A SMART Groundwater Portal: An OGC Web Services Framework for Hydrology to Improve Data Access and Visualisation in New Zealand." *Computers and Geosciences* 69: 78–86. doi: 10.1016/j.cageo.2014.04.016.
- Klug, H., R. Schörghofer, and S. Reichel. 2014. "A Climate Change Capitalisation Knowledge Inventory Platform." In *GI Forum 2014: Geospatial Innovation for Society*, edited by R. Vogler, A. Car, J. Strobl, and G. Griesebner, 57–66. Berlin/Offenbach: Herbert Wichmann.
- Lopez-Marrero, T. 2010. "An Integrative Approach to Study and Promote Natural Hazards Adaptive Capacity: A Case Study of Two Flood-Prone Communities in Puerto Rico." *Geographical Journal* 176: 150–163. doi: 10.1111/j.1475-4959.2010.00353.x.
- Lyle, G. 2015. "Understanding the Nested, Multi-Scale, Spatial and Hierarchical Nature of Future Climate Change Adaptation Decision Making in Agricultural Regions: A Narrative Literature Review." *Journal of Rural Studies* 37: 38–49. doi: 10.1016/j.jrurstud.2014.10.004.
- Malczewski, J. 2006. "GIS-Based Multicriteria Decision Analysis: A Survey of the Literature." *International Journal of Geographical Information Science* 20: 703–726. doi: 10.1080/13658810600661508.
- Mittlböck, M., L. Morper-Busch, C. Atzl, and H. Klug. 2012. Task-orientierte Web-Maps zur kompakten Visualisierung kartographischer Inhalte. In *Angewandte Geoinformatik 2012, Beiträge zum 24. AGIT-Symposium in Salzburg*, edited by J. Strobl, T. Blaschke, and G. Griesebner, 333–338. Salzburg: Wichmann.
- Norbiato, D., M. Borga, M. Sangati, and F. Zanon. 2007. "Regional Frequency Analysis of Extreme Precipitation in the Eastern Italian Alps and the August 29, 2003 Flash Flood." *Journal of Hydrology* 345: 149–166. doi: 10.1016/j.jhydrol.2007.07.009.
- O'Neill, S.J., and M. Boykoff. 2011. "The Role of New Media in Engaging Individuals with Climate Change." In *Engaging the Public with Climate Change: Communication and Behaviour Change*, edited by L. Whitmarsh, S.J. O'Neill, and I. Lorenzoni, 233–251. London: Earthscan.
- Paul, F., A. Kääb, and W. Haeberli. 2007. "Recent Glacier Changes in the Alps Observed by Satellite: Consequences for Future Monitoring Strategies." *Global and Planetary Change* 56, 111–122. doi: 10.1016/j.gloplacha.2006.07.007.
- Rannow, S., W. Loibl, S. Greiving, D. Gruehn, and B.C. Meyer. 2010. "Potential Impacts of Climate Change in Germany: Identifying Regional Priorities for Adaptation Activities in Spatial Planning." *Landscape and Urban Planning* 98 (3–4): 160–171. doi: 10.1016/j.landurbplan.2010.08.017.
- Roy, B. 1978. "ELECTRE III: un algorithme de classement fonde sur une representation floue des preferences en presence de criteres multiples". *Cahiers Centre d'Etudes REch. Oper* 20 (1): 3–24.
- Ruiz-Villanueva, V., M. Stoffel, G. Bussi, F. Frances, and C. Brethaut. 2015. "Climate Change Impacts on Discharges of the Rhone River in Lyon by the End of the Twenty-First Century: Model Results and Implications." *Regional Environmental Change* 15 (3): 505–515. doi: 10.1007/s10113-014-0707-8.
- Schär, C., P.L. Vidale, D. Luthi, C. Frei, C. Haberli, M.A. Liniger, and C. Appenzeller. 2004. "The Role of Increasing Temperature Variability in European Summer Heatwaves." *Nature* 427: 332–336.
- Steger, C., S. Kotlarski, T. Jonas, and C. Schär. 2013. "Alpine Snow Cover in a Changing Climate: A Regional Climate Model Perspective." *Climate Dynamics* 41: 735–754. doi: 10.1007/s00382-012-1545-3.
- Stagl, J., F.F. Hattermann, and K. Vohland. 2015. "Exposure to Climate Change in Central Europe: What Can be Gained from Regional Climate Projections for Management Decisions of Protected Areas?" *Regional Environmental Change* 15 (7): 1409–1419. doi: 10.1007/s10113-014-0704-y.
- Thielen, A.H., H. Cammerer, C. Dobler, J. Lammel, and F. Schöberl. 2014. "Estimating Changes in Flood Risks and Benefits of Non-Structural Adaptation Strategies: A Case Study from Tyrol, Austria". *Mitigation and Adaptation Strategies for Global Change* 21 (3): 343–376. doi: 10.1007/s11027-014-9602-3
- Tompkins, E.L., W.N. Adger, E. Boyd, S. Nicholson-Cole, K. Weatherhead, and N. Arnell. 2010. "Observed Adaptation to Climate Change: UK Evidence of Transition to a Well-Adapting Society." *Global Environmental Change* 20 (4): 627–635. doi: 10.1016/j.gloenvcha.2010.05.001.
- Young, H.P. 1974. "An Axiomatization of Borda's Rule." *Journal of Economic Theory* 9: 43–52.
- Zimmermann, N.E., E. Gebetsroither, J. Züger, D. Schmatz, and A. Psomas. 2013. *Future Climate of the European Alps*. Freiburg im Breisgau: FVA.