A stakeholder-based assessment of barriers to climate change adaptation in a water-scarce basin in Spain

Paloma Esteve^{1,2} · Consuelo Varela-Ortega^{1,2} · Thomas E. Downing³

Received: 27 June 2017 / Accepted: 8 June 2018 / Published online: 27 June 2018
© The Author(s) 2018

Abstract

In the last decade, increasing evidence of climate change fostered the development of multiple initiatives for adaptation. However, there are few examples in which adaptation has been successfully implemented, evidencing the need for improving understanding about the socio-institutional context of adaptation processes and the underlying causes of barriers to adaptation. In this research, we developed a stakeholder-based assessment of barriers to the adoption of climate adaptation options for irrigation in the Guadiana basin, one of Spain's most climate-vulnerable basins. Based on social network mapping, we elicited potential barriers to adaptation in the water sector. Using stakeholder questionnaires, we assessed the impact of the identified barriers on the implementation of selected adaptation measures. Results highlight the low acceptance of planned adaptation by stakeholders, and the lack of awareness and of a common understanding among the different actors as preeminent barriers to adaptation, potentially caused by insufficient interactions between water users, the scientific community and environmental groups. The role of the government as a catalyst of those interactions can be crucial for overcoming those barriers. Acknowledged water management instruments, such as water tariffs and quotas, may face the greatest barriers, while widely accepted adaptation measures, such as irrigation modernisation, can contribute to overcoming the obstacles for the implementation of more controversial measures. Overall, the results of this research contribute to climate change adaptation providing a better understanding of the social dimension of adaptation processes, potential barriers to overcome and the feasibility of specific measures.

Keywords Adaptation · Barriers · Climate change · Irrigation · Social network mapping · Water management

Editor: James Ford

Electronic supplementary material The online version of this article (<https://doi.org/10.1007/s10113-018-1366-y>) contains supplementary material, which is available to authorized users.

✉ Paloma Esteve
paloma.esteve@upm.es

Consuelo Varela-Ortega
consuelo.varela@upm.es

Thomas E. Downing
TDowning@ClimateAdaptation.cc

¹ Department of Agricultural Economics, Statistics and Management, Universidad Politécnica de Madrid, Madrid, Spain

² Research Centre for the Management of Agricultural and Environmental Risks, Universidad Politécnica de Madrid, Madrid, Spain

³ The Global Climate Adaptation Partnership, Oxford, United Kingdom

Introduction

Despite the observed effects of climate change in many parts of the world (EEA 2012; IPCC 2013), and the efforts of governments in developing adaptation strategies, there are few cases in which climate change adaptation processes have been effectively accomplished (Moser and Ekstrom 2010; Eisenack et al. 2014). The relatively recent development of knowledge on climate change impacts and vulnerability at the local level, coupled with its associated high uncertainty, has limited the scope for action on adaptation. However, beyond this, there also exist an array of barriers that have constrained the implementation of adaptation actions, as widely discussed in the literature (e.g. Moser and Ekstrom 2010; Eisenack and Stecker 2012; Biesbroek et al. 2013). There is an increasingly rich body of literature that identifies and lists barriers to adaptation. Jones and Boyd (2011) categorised barriers as natural, human and informational, and social. These account for different aspects that may constrain adaptation such as natural and physical conditions, knowledge, technology and finance,

and also norms and institutions. However, even if identifying barriers is a crucial step for achieving adaptation, there is still a need to better understand the underlying causes behind those adaptation barriers and ways to overcome them (Eisenack et al. 2014).

Adaptation to climate change is a dynamic process that occurs at multiple temporal, spatial and decision-making scales (Smit and Wandel 2006; Agrawal 2010; Downing 2012). Adaptation processes often involve short-term actions, as well as long-term processes that imply economic, social, and institutional changes. These processes take place at the local level, with implications at the regional and national levels (and vice-versa), whilst simultaneously involving the actions of individuals, communities and decision-makers that frequently are interconnected.

Agriculture, as an economic sector highly affected by climate events, is one of the sectors where adaptation will be most crucial. In the case of irrigated agriculture, adaptation must deal not only with the effects of climate change on crop growth, but also with the pernicious effects on water resources availability. There are a wide range of adaptation measures available for agricultural water management, as reflected in the literature (e.g. Iglesias and Garrote 2015). Examples include improved irrigation technologies, adaptation of crop varieties, new water infrastructures and policies that promote irrigation efficiency through economic incentives. Implementation of these measures requires varied types of capital and interactions between different actors at diverse scales. For example, implementation of new technologies at the farm level firstly requires farmers' willingness to adopt such technologies, but may also require governmental financial support, or technical support from agricultural extension services. The high dependence of adaptation actions on different resources and actors, along with social and institutional arrangements, suggests that the outcome of adaptation processes is determined by multiple and overlapping social processes (Jones and Boyd 2011) in which a number of obstacles can arise. Frequently acknowledged barriers to farmers' adaptation include the lack of financial resources (especially access to credit), lack of technical options or knowledge of technical options, low awareness, inadequate climate information and information of adaptation options (e.g. Deressa et al. 2009; Esham and Garforth 2013; Dang et al. 2014). Literature in the field of water resources management not only highlights physical, technical and financial barriers but also emphasises the relevance of governance and the importance of formulating an enabling institutional and social environment that can facilitate adaptation (Huntjens et al. 2012; Barnett et al. 2015). Institutional constructs that promote stakeholder involvement and cooperation, interagency coordination or cross-scale integration may contribute to the planning and implementation of adaptation actions (Bates et al. 2008; Krysanova et al. 2010; Jiménez Cisneros et al. 2014).

Social networks and their link to climate change adaptation

Constraints to climate change adaptation frequently arise from a lack of access to appropriate resources including financial, natural, human and also social capital. As a source of resilience, social capital is crucial for building adaptive capacity of social-ecological systems (Folke et al. 2005). It may be essential for the implementation of adaptation processes, especially in the context of natural resource management and climate change (Adger 2003). Several scholars have addressed the relation between social capital and adaptation to climate change (e.g. Adger 2003; Pelling and High 2005), paying attention to those elements of social relations that are key to the construction of social capital such as networks, rules and trust (Putnam 1995). The differential structures and nature of relation in social networks may deliver either positive or negative outcomes (Adger 2003; Paul et al. 2016). For example, Wolf et al. (2010) and Paul et al. (2016) found that bonding relations (within a social group) may increase the vulnerability of certain individuals or groups because of reduced private adaptive behaviour. Adger (2003) explained that society-state networking relations (between different groups) may provide important contributions to adaptation, by taking advantage of significant synergies. They give rise to new institutional arrangements and co-management structures, provide access for individuals and communities to knowledge and resources, take advantage of governmental capacity to manage resources and infrastructures and promote the evolution of governmental institutions to deliver policy and social learning (Adger 2003; Paul et al. 2016).

A social network is the set of actors (individuals, organisations, institutions...) and the relationships established between them (Marin and Wellman 2011) through different socially relevant links such as information exchange, power relations, and other mechanisms. Analysis of social networks has provided insights into natural resource governance and climate change adaptation (Bodin and Crona 2009; Stein et al. 2011; Bharwani et al. 2013; Lienert et al. 2013). Several authors have demonstrated that formal and informal social networks can determine resilience and adaptive capacity (Pelling et al. 2008; Scheffran et al. 2012), whilst emphasising the importance of informal networks and information flows in enhancing learning and innovation, and supporting adaptive action (Pelling et al. 2008). Berkes (2009) stresses the role of information in managing social-ecological systems and explains how social networks facilitate the flow of information across organisations at different scales. In the context of adaptive co-management, Folke et al. (2005) also elaborate on the role of multi-level social networks in fostering collaboration that deliver increased trust and enhanced information and contribute to the development of common understanding regarding policy issues. Certain types of social network structures increase

response capacity and flexibility and create opportunities for adaptation to long-term climate change risks (Berkes 2009; Pahl-Wostl and Knieper 2014). Actor centrality in a network can determine its influence and leadership, whereas density and cohesion have been argued to contribute to collective action, common understanding and shared values in a system (Bodin and Crona 2009; Fischer and Jasny 2017). These are cross-cutting elements without which barriers may arise at every stage in the adaptation process (Moser and Ekstrom 2010). Therefore, looking at the socio-institutional contexts and understanding social networks involved in adaptation can substantially contribute in enhancing the understanding of the underlying causes of climate change adaptation barriers, whilst also contributing to the identification of potential avenues for overcoming such barriers.

Objective of the research

In this context, the objective of this research is to assess potential barriers to climate change adaptation, by improving the understanding of the socio-institutional context for adaptation, and reflect on the relevance of those barriers by looking at their impact on specific adaptation measures. The paper develops a case study in a Spanish river basin, where previous studies (Esteve et al. 2015; Varela-Ortega et al. 2016) analysed potential adaptation measures for the irrigation sector. These studies considered the contribution of adaptation measures in reducing the effects of water shortages, and their socio-economic impact. However, they did not consider the barriers that implementation of such measures may face. In this regard, this research tries to advance the understanding of adaptation processes and the feasibility of specific adaptation measures looking at the social networks of the basin to identify potential climate change adaptation barriers. Then, based on stakeholder opinions, we will evaluate how they may affect the implementation of specific adaptation measures.

Case study

The Guadiana River Basin is one of Spain's most vulnerable basins to the effects of climate change (CEDEX 2011). Agriculture is the most prominent economic sector within the basin, in terms of water consumption ($\approx 90\%$) and socio-economic importance (CHG 2013). Therefore, climate change impacts on water resources and agriculture within the basin may have severe socio-economic implications.

The Middle Guadiana (Fig. 1), located in south-western Spain, covers an area of around 34,000 km² and includes an irrigation extension of 140,000 ha. With an average annual precipitation of 590 mm, and an annual water inflow of 4270 Mm³ (CHG 2013), this area is heavily supported by a large water storage capacity (8000 Mm³) that ensures water

volumes for irrigation activities. However, this large water storage together with a water pricing system not based on actual water use has resulted in extensive water consumption on local farms, low water use efficiency, low incentives for irrigation modernisation and water saving, and limited consideration of environmental concerns.

In this context, climate change emerges as an important threat to the irrigation sector and the aquatic ecosystems of the Middle Guadiana. Recent studies by Esteve et al. (2015) estimate a 15% decrease in river runoff during the period 2011–2040, and a 35% reduction in the period 2041–2070 under an A2 climate change scenario. At the same time, increased temperatures and reduced precipitation may result in increased agricultural, industrial and urban demands, with more frequent droughts expected to produce large gaps between water demand and supply (Esteve et al. 2015; Varela-Ortega et al. 2016). Therefore, adaptation of water users to climate change seems crucial in the basin, with the water, agricultural and environmental administrations in the process of facilitating this adaptation.

Climate change adaptation policy is primarily the responsibility of the regional environmental administration, which in 2013 enacted the Regional Adaptation Plan for the Water Sector (Junta de Extremadura 2013). However, there is an intertwined set of actors determining adaptive capacity and developing adaptation activities, including water users and different administrations as well as other actors. It is within this intertwined context that understanding existing adaptation barriers and their underlying causes requires a detailed consideration of the different actors, and social network interactions taking place within the basin.

Methods

To attain the proposed research objectives, we developed the methodological framework summarised in Fig. 2. It includes three phases: (1) an analysis of social networks, (2) the elicitation of adaptation barriers and (3) an analysis of the impact of these barriers on the implementation of specific adaptation measures. Each stage is based upon the involvement of stakeholders and experts through workshops, interviews or questionnaires.

The first phase of this research focused upon the analysis of social networks in the Middle Guadiana water sector. Different methods for analysing social networks, both quantitative and qualitative, have been developed to suit varied research contexts and constraints. Conventional Social Network Analysis (SNA) techniques map and measure the relationships between actors making use of visual images (social network maps or sociograms) and mathematical and/or computational models (Freeman 2004). Quantitative SNA techniques are based on extensive social

Fig. 1 The Middle Guadiana Basin

Fig. 2 Methodological framework for the assessment of barriers to adaptation

network data usually obtained through questionnaires or interviews. However, this data gathering can be very time-consuming and may limit learning outcomes for participants (Schiffer and Hauk 2010).

Alternatively to traditional data-intensive SNA, qualitative social network analysis or social network mapping (SNM) does not explicitly quantify actors' relations, but studies their influence in a qualitative manner drawing conclusions about a system's functioning based on network topologies (Bharwani et al. 2013). This kind of qualitative approach is usually based on stakeholder participation (e.g. interviews, focus groups). SNM also has similar limitations to that of SNA but it can be suitable for rapid assessments in the context of stakeholder workshops encouraging participation, dialogue between stakeholder groups, and learning (Schiffer and Hauk 2010; Bharwani et al. 2013).

In this research, we applied SNM within the context of the EU Project MEDIATION (Methodology for Effective Decision-Making on Impacts and Adaptation, European Commission, Project No. 244012). Following stakeholder mapping and the review of key public documents, the analysis of social networks started with a participatory SNM exercise developed in a workshop. This exercise followed the NetMap approach (Schiffer and Hauk 2010), a participatory SNM method that maps complex networks incorporating additional qualitative information such as an actor's role, influence, goals and the main strengths and weaknesses in the adaptation arena. Participants worked in three different groups: water administration, farmers and environment-related groups (administration and NGOs). Each group produced a SNM representing the key institutions and actors, whilst also highlighting the links between these groups in terms of flows of financing, information and implementation capacity. At the end of the workshop, the three SNMs were presented and discussed in a plenary session (see Bharwani et al. (2013) and Varela-Ortega et al. (2016) for a detailed description of the SNM exercise). After the workshop, we systematically integrated the three independent maps to produce an aggregated SNM for the Middle Guadiana basin, which was subsequently discussed, completed and validated with key selected stakeholders and experts.

The second phase consisted in the elicitation of a list of climate change adaptation barriers based upon the analysis of the SNM. Network properties, such as its structure, centrality of actors and connections between them, their roles and influence in the network, were analysed and later discussed with stakeholders and experts through semi-structured interviews. These interviews permitted the identification of elements determined by network characteristics (e.g. institutional coordination) that may hinder adaptation processes. Based on these, a final list of potential climate change adaptation barriers in the Middle Guadiana basin water sector was developed with stakeholders.

The final stage of the process consisted in the assessment of the effect of the identified barriers on the implementation of specific adaptation measures. For this, a list of relevant adaptation measures for the irrigation sector was developed using the Regional Adaptation Plan for Water Resources (Junta de Extremadura 2013) and previous studies (Esteve et al. 2015; Varela-Ortega et al. 2016). Using individual questionnaires, 20 stakeholders and experts rated from 0 to 5 the relevance of each barrier with respect to the implementation of the measures considered. 0 was utilised to designate barriers that are not relevant to a specific measure, and 5, those issues that may strongly affect the implementation of a measure.

The stakeholder groups and experts involved in the process included representatives from the Guadiana River Basin Authority, the Spanish Office for Climate Change, the Regional Department of Agriculture and Environment (both from the Irrigation Service and from the Environmental Protection Service), irrigation communities, three different environmental NGOs and scientists from the fields of water, agriculture and climate change. In total, 18 stakeholders and experts participated in the workshop and 20 in the subsequent interviews and questionnaires. Table 1 in Online Resource 1 summarises the main questions addressed at every phase of the process.

Finally, it is important to refer here to the limitations of these methods. With the aim of presenting a consensual and synthetic view of social networks in the Middle Guadiana for discussion with stakeholders, the aggregation of the three maps produced in the workshop made it necessary to make decisions about actors and the ties to be included or removed from the final social network map. To overcome this issue, the aggregated map was discussed, completed and validated with stakeholders. Additional limitations of the methodology are those common to most participatory processes, such as the potential bias of results due to the subjectivity of participants and the balance of the stakeholder group.

Results and discussion

This section presents and discusses the results of this study, structured according to the three phases of the research outlined above. First, we introduce the results of the SNM, describing the structure of the integrated network, the role and relevance of actors, and the most important links between them. Second, we present and discuss the insights gained from the analysis and discussion with stakeholders of the SNM results to identify a set of potential barriers to climate change adaptation. Finally, we evaluate the effect that these barriers may have upon the implementation of selected adaptation measures, and we elaborate on their implications for climate change adaptation within the irrigation sector of the Middle Guadiana basin.

Analysis of social networks

Figure 3 depicts the aggregated SNM, in which circles represent the different actors of the Middle Guadiana, and arrows depict the relationships among them in terms of flows of financing (blue), information (yellow) and implementation capacity (red). Bold arrows symbolise formal and strong flows, which represent relations based on official governmental initiatives, which are perceived as strong and stable along time. Dashed arrows represent informal flows or flows perceived as 'weak' or unstable, in which the initiative and role of the government and formal institutions is less prominent or is dependent on governmental initiatives perceived as less stable and weak. The colour and size of the circles demonstrate the number of ties for each actor, suggesting the most influential within the system. Larger and darker circles represent actors of greater influence.

Looking at the network cohesion, the structure of the network shows different subgroups easily identifiable. Firstly, there is a notable vertical axis, which is central to the network and corresponds to the different governmental levels, including the European Union (EU), the Ministry of Agriculture and

Environment (national level), the River Basin Authority (RBA) (sub-national, basin level), the Regional Department of Agriculture and Environment (sub-national, regional level) and the local authorities (municipalities). The scientific community and the environmental groups are on the right side of the network, connected to the administration and also to each other. The different users, on the left side of the network, are not tied to each other. The network shows domestic and industrial users as peripheral actors, linked to the administration at different levels. Finally, irrigation farmers form a subgroup with the irrigation communities and producer organisations, with links between themselves, with the governmental bodies at different levels and with the EU. The fact that industrial and domestic users are marginal actors is consistent with the fact that, in terms of water consumption, agriculture is the key actor. With 90% of total water withdrawals, the need for adaptation to future water scarcity is critical for the agricultural sector.

The network demonstrates the clear centrality of governmental bodies, within which the Regional Department of Agriculture and Environment and the Ministry of Agriculture and Environment are the most influential actors

Fig. 3 Social network map of the water sector adaptation system

according to the high number of links with other actors. With slightly less relevance, the River Basin Authority (RBA) plays also an important role. The governmental administrations at different levels are the key actors transferring information, financing and capacity to water users. They act as a bridge between water users, the scientific community and environmental groups. These last two groups are important sources of information, but have little interaction with water users. The most relevant actors among the water users are farmers, which are primary receivers of flows of financing, information and capacity from different governmental bodies. Also, they receive information and capacities from the irrigation communities and agricultural producer organisations. The irrigation communities, which integrate farmers from the same irrigation district, are linked with administrative bodies at higher levels including both the Ministry of Agriculture and Environment and the EU which provide information, funding and different capacities. Irrigation communities also act as bridges between farmers and governments, providing support and offering a voice to small farmers whose views would otherwise rarely be considered in management and policy-making processes.

Looking at specific flows, financing flows considered here are those that fund any specific action that may facilitate adaptation, including funds from agricultural and water policies. Formal flows of financing correspond to stable funds from the budgets of certain policies specifically devoted to climate change adaptation (e.g. funds from rural development programmes) as well as other non-climate-specific funds such as those devoted to water supply system maintenance and fees paid by farmers to the irrigation communities for common investments, etc. Informal financing flows are those not stable in the medium- to long-term and are perceived as less reliable (the amounts fluctuate and can be removed under economic stress or as policy priorities change). The map shows numerous informal financing flows coming from the EU and the national and regional administrations directed towards agricultural water users (farmers and irrigation communities).

Information flows include knowledge and information that may support adaptation, mainly related to climate change impacts, available adaptation options, technical and agronomic recommendations, etc. Most of the formal information flows correspond to those that exist between the administrations and the water users. At the same time, there are a considerable number of informal/weak information flows, especially those linking scientists and environmental groups with other actors.

Implementation capacity flows refer to different actions, policies and institutional rules that provide all actors with capacity to adapt. In the Middle Guadiana network, formal capacity flows emanate firstly from the EU and are subsequently directed towards the National government, the RBA and the Regional government, and finally to users. The National Government provides capacity to all other governmental bodies, mostly through the adoption of plans and strategies and

other institutional arrangements. The RBA and the Regional Government, through the elaboration of water management and adaptation plans, also provide farmers and other water users with the capacity to adapt, as these plans determine the rules for water use and create incentives for actions on adaptation.

Elicitation of barriers to adaptation

Based on the results of the SNM shown in the previous section, we analyse and discuss the network characteristics and their links to potential climate change adaptation barriers in the Middle Guadiana. The properties of the network can have according to stakeholders and the literature (Berkes 2009; Bodin and Crona 2009; Stein et al. 2011; Bharwani et al. 2013; Lienert et al. 2013) relevant implications for elements such as policy coordination and consistency, level of knowledge and awareness, and policy acceptance (among others). These elements, identified by several authors (e.g. Moser and Ekstrom 2010; Measham et al. 2011) as potentially creating adaptation barriers, are discussed in the following sections.

Policy coordination, consistency and control

Among the most evident elements of the network is the centrality of the governmental bodies at different levels, and especially the Regional Department for Agriculture and Environment as the responsible body for adaptation policy. The network shows multiple formal links between the different administrations, indicating a well-established hierarchy. There is a clear top-down structure, but the relevance of lower administrative levels, such as the Regional Department of Agriculture and Environment, shows a level of decentralisation that may offer increased flexibility and response capacity resulting in improved implementation of adaptation processes (Pahl-Wostl and Knieper 2014).

However, this structure may entail as well coordination issues. The consulted stakeholders highlighted, in line with literature (Ivey et al. 2004; Engle 2011), how coordination and integration at different organisational and institutional levels are crucial to build adaptive capacity. For example, the network shows the RBA is a central actor with respect to information and implementation capacity, but not in terms of financing. This suggests the need for good coordination between the RBA and the Regional Government, so that the RBA's capacity is effectively translated into actions that require public financing and the Regional Government's actions are in line with the RBA's water management priorities. A consistent policy framework and effective coordination between different administrative levels are crucial elements without which adaptation processes may be hindered (Moser and Ekstrom 2010; Measham et al. 2011; Mukheibir et al. 2013). Also, multi-level coordination is reported among the

most relevant challenges for integrated water management (UNEP 2012).

Additional coordination issues were suggested by stakeholders that explained that regional policy on agriculture, environment and climate change are competence of the Regional Department of Agriculture and Environment but under different agencies. Participants explained that the development of adaptation plans for water and agriculture, undertaken by the Environment Agency, was not fully coordinated with the Agricultural Agency which can result in an inadequate planning and implementation, and lack of control of compliance with policy measures.

Knowledge, awareness, common understanding and stakeholder acceptance

A second important aspect emphasised by the participants is the lack of links between water users and the environmental groups and scientific community, which are both perceived as relevant information providers. This may indicate low levels of climate change awareness. According to stakeholders, development of further connections between water users and environmental groups may be prevented by their apparent antagonistic goals, which, together with the low awareness, may hinder the development of a common understanding among the different actors, reducing the likelihood of joint actions in the basin (Adger et al. 2009; Bodin and Crona 2009; Moser and Ekstrom 2010). In line with other studies (Albizua and Zografos 2014), experts and stakeholders interviewed stressed that scientists apparently do not have conflicting objectives with other actors in the system and could contribute to improved knowledge transfer, common understanding and raising awareness among users. However, the limited links between the scientific community and water users in the current system may minimise the impact of science on the whole system. In line with this, the EU Commission Report on the status of implementation of the WFD (EC 2012) highlights the need for improved communication from the scientific community to promote effective policy development and to increase legitimacy and stakeholder acceptance.

Instead, current information streams in the network are highly dependent on the different governmental bodies, which act, as mentioned above, as bridges between actors in the network. In this sense, stakeholders highlighted the importance of public participation in water management policy-making as a tool for both strengthening and formalising information flows. However, despite many policy-making processes demanding stakeholder involvement and public participation, some participants argued that such information and consultations do not always reach stakeholders effectively. At the same time, there are some informal flows of information, especially those linking scientists and

environmental groups, with other actors. In this respect, consideration should be made of the discussion of Pelling et al. (2008) who argued that these informal interactions, or *shadow systems*, could be important contributors to social learning and enhance adaptive capacity. However, according to stakeholder opinions, many of these informal flows may be weak or ineffective due to low stability or continuity.

Financial and technological resources, and additional considerations

The Middle Guadiana SNM shows that there are a considerable number of financial flows reaching agricultural water users. However, farmers interviewed argued that the lack of financial resources may limit the access to new technologies in the farms, being both the access to financing and to technology adaptation barriers frequently mentioned in the literature (Moser and Ekstrom 2010). Also, some of the experts interviewed stressed that a high dependency on financial support from the administration may make farmers less proactive and may reduce their incentives to adapt, therefore making them more vulnerable. This may suggest an additional constraint to adaptation, if financial flows are discontinued due to economic recession or if there are changes to the policies that provide such funds.

Finally, stakeholders mentioned the difficulties in the identification of appropriate thresholds as a barrier for the implementation of certain measures. The already-explained effect of limited connections between the scientific community and water users on knowledge transfer and common understanding may in turn trigger difficulties in the identification of appropriate thresholds for the implementation of certain measures. Specifically, farmers explained that some policy measures, such as the use of water tariffs for cost recovery and the maintenance of environmental flows in rivers, are difficult to apply. Identifying the appropriate price of water or the appropriate minimum river flow (thresholds) requires not only very specific knowledge but also a common understanding of the costs of water that should be recovered, and the minimum standards for aquatic ecosystems that should be maintained.

Summary of barriers

To summarise, analysis of the network permitted the identification of a set of potential barriers that may affect implementation of selected adaptation measures within the basin. They are summarised as follows:

- Lack of coordination
- Lack of appropriate policy framework or conflicting policy framework
- Lack of appropriate control of policy implementation
- Lack of sufficient knowledge

- Low awareness
- Lack of a common understanding
- Lack of acceptance
- Lack of financial resources
- Lack of access to appropriate technology
- Difficulty for threshold identification

Analysis of the impact of barriers on climate change adaptation measures

This section elaborates the impact of the identified barriers on the implementation of specific adaptation measures, based on stakeholder rating of the barriers' strength across measures. Then, based on the analysis above, we reflect on potential avenues to support the implementation of these measures through a more enabling socio-institutional context.

The adaptation measures considered, intended to reduce the vulnerability of irrigation farmers and of aquatic ecosystems, were selected from the basin's climate adaptation policy (Regional Climate Change Adaptation Plan for Water Resources) and have been underlined by different authors (Esteve et al. 2015; Varela-Ortega et al. 2016) as promising options for adaptation in the basin. They include (i) water pricing for cost recovery, as a measure that incentivises water use efficiency; (ii) limiting irrigated water consumption, through exhaustive controls of compliance with water allotments and eventual reductions; (iii) modernisation of water conveyance and irrigation systems (substitution of traditional gravity-based irrigation methods by pressurised systems, especially drip irrigation); (iv) establishment of environmental flows to protect aquatic ecosystems; and (v) adaptation of cropping patterns towards better adapted crops or varieties.

Figure 4, divided in six panels, summarises the results. Panel "a" shows the ranking of barriers to adaptation according to their average impact on the implementation of adaptation measures (average value across measures). The impact of each barrier is expressed from 0 to 5, representing the range between the lowest and the highest impact that each barrier could have on the implementation of each selected adaptation measure. The remaining panels (b to f) show the rating of the barriers for each measure considering the opinions of all stakeholder groups involved in this research. Results of the rating of barriers for each measure and by stakeholder group are shown in Online Resource 2.

The results demonstrate that stakeholders' lack of acceptance for certain measures and the lack of a common understanding among the actors of the basin are perceived as the strongest barriers to implementation of climate change adaptation measures in the Middle Guadiana (both above 3). The low awareness of stakeholders about climate change adaptation needs emerges also as a moderate-to-strong barrier (2.75). In the moderate range (between 2.5 and 1.5), we find lack of

financial resources, lack of institutional coordination, lack of an adequate regulatory framework, difficulty for establishing appropriate thresholds for the different measures and lack of control of policy implementation. All of these moderate and strong barriers were similarly considered as barriers to adaptation in the Middle Guadiana by Krysanova et al. (2010), except for the difficulty for threshold identification. The fact that lack of coordination is ranked in the fifth position as a moderate barrier may be surprising, considering the prominence of this issue in the water governance field (Krysanova et al. 2010; UNEP 2012), and for stakeholders during interviews. This may be explained by the fact that stakeholders were asked to evaluate the impact of each barrier on the implementation of specific measures. However, the coordination between administrations may more specifically contribute to the creation of an enabling environment for the implementation of adaptation processes, rather than it being an element directly necessary for the implementation of the adaptation measures considered.

Finally, stakeholders and experts perceived the lack of both adequate technologies and knowledge for implementing adaptation measures in the Middle Guadiana as not very relevant, with these elements found at the bottom of the rank (below 1.5).

Looking at the impact of the barriers on specific adaptation measures, Fig. 4 shows that the relevance of the barriers varies widely depending on the adaptation measure considered (see Fig. 4b–f). According to stakeholders and experts, the measures that on average may face the greatest obstacles in their implementation are the use of water pricing for cost recovery (b), maintaining environmental flows (e) and limiting irrigated water consumption (c). The most relevant barriers for the implementation of those measures are a lack of a common understanding, low awareness and lack of acceptance by the affected stakeholders. Lack of control from the authorities is particularly relevant for limiting irrigated water consumption (c) and also for water pricing (b) as it relies on the measurement of water use. The fact that these measures face the strongest barriers may constitute an important concern for water managers, as these are measures consistently promoted by water management regulations. Previous studies (Esteve et al. 2015; Varela-Ortega et al. 2016) emphasised the potential of these instruments in reducing the gap between water supply and demand under climate change, through the promotion of more efficient management of water by farmers. However, the present research highlights potential opposition from stakeholders, in line with other studies (e.g. Albiac et al. 2008; Blanco-Gutiérrez et al. 2011) and emphasises the relevance of actors' cooperation, acceptance and policy control for the success of these measures. Moreover, according to the analysis in the previous section, promoting and enhancing relations between water users, the scientific community and environmental groups could contribute to partially overcome the

Fig. 4 Impact of barriers on the implementation of selected climate change adaptation measures. **a** Average impact of barriers. **b** Water pricing/cost recovery. **c** Limitation of irrigation water consumption. **d** Modernisation. **e** Environmental flows. **f** Adaptation of cropping patterns

obstacles in the implementation of such measures. Scientists can provide knowledge and information that improve awareness, and given their perceived neutrality they can contribute to create a shared understanding that facilitates the implementation of the mentioned adaptation measures.

Adaptation of cropping patterns (Fig. 4f) and modernisation of water conveyance and irrigation systems (Fig. 4d) would not however be so severely affected by the barriers considered as the previous three. This is consistent with the results of Varela-Ortega et al. (2016), which highlighted these two measures as highly adequate options that besides reducing the vulnerability of farmers and ecosystems show a high financial and political feasibility. Iglesias and Garrote (2015) showed that changing crops and cropping patterns would present a good benefit-to-effort ratio as an adaptation practice for agricultural water management in Europe. Our results suggest that changing cropping patterns would be an easily implementable adaptation measure. This measure could suffer from farmers' lack of awareness about adaptation needs, suggesting that more information and knowledge obtained through interactions with administrations at different levels and from scientists coupled with appropriate incentives could be needed. However, it should also be noted that according to stakeholders, in some areas, there are few alternative options available due to soil quality constraints (e.g. land devoted to rice cultivation).

The case of irrigation modernisation may have particular implications. It has been argued that modernisation could result in unwanted increase of water consumption or energy use (López-Gunn et al. 2012). However, several authors (Scott et

al. 2014; Berbel et al. 2017) explain that some of these unintended consequences could be avoided by controlling and limiting water use and establishing adequate water pricing. At the same time, Berbel et al. (2007) and Esteve et al. (2015) explain that irrigation modernisation can cushion the negative economic impacts of water pricing and of reduced water allotments through increased water-saving potential, which evidences clear synergies of the joint implementation of these measures. According to our analysis, these synergies are further aided by the fact that irrigation modernisation does not face significant barriers and by reducing the negative impact of measures that constrain the use of water, it could contribute to farmers' acceptance, reducing the obstacles for implementation of such economically unfavourable measures. However, the lack of financial resources could be an obstacle in making the necessary investments for modernisation (Fig. 4d).

Summary and conclusions

Recent experience in climate change adaptation across the world has demonstrated the presence of barriers that hinder the implementation of adaptation measures. Developing effective climate change adaptation strategies requires going beyond the recognition of barriers, towards an improved understanding of their roots in the socio-institutional context. In line with this, this paper has presented an analysis of climate change adaptation barriers in Spain's Middle Guadiana basin

that contribute to the adaptation debate by identifying potential barriers and their causes, through the analysis of the socio-institutional aspects that determine adaptation within the basin. This analysis of adaptation barriers is then used to evaluate the feasibility of adaptation measures included in the region's adaptation plan.

The methodology applied, based on participatory SNM and stakeholder questionnaires, proved to be useful for visualising the many actors playing a role in the adaptation arena. Despite limitations inherent to participatory methods (e.g. bias) and to the analysis of social networks (e.g. the difficulty to set the boundaries of a system), the methods applied also offered a means for improving the understanding of the complex interactions between actors that may create barriers at every stage of the adaptation process.

The results highlighted the key role of regional administrations in transferring knowledge, financing and capacities required for adaptation, and also the importance of coordination of these regional administrations with other governmental bodies and actors. Low levels of acceptance by stakeholders, low climate change awareness and a lack of a common understanding among the different actors are preeminent barriers to adaptation that can be caused by insufficient interactions between water users, the scientific community and environmental groups. However, public institutions and governmental bodies at different scales can greatly contribute in promoting multi-actor interactions, improving knowledge transfer, and building common views and goals in the basin, contributing to lessen the impact of those barriers.

The consideration of the impacts of barriers on specific adaptation measures revealed that certain adaptation measures central to water management, such as water tariffs and quotas, may face significant barriers in their implementation. More importantly, our analysis evidenced that there are accepted and easily implementable measures, such as irrigation modernisation, that can contribute to overcoming the obstacles for the implementation of those controversial measures. Thus, the combination of different adaptation measures can also contribute to reduce some of the barriers, taking advantage of existing synergies between measures.

Overall, this research has demonstrated that it is critical to look at the social and institutional contexts in which adaptation processes take place. The measures included in water management and climate change adaptation plans, also supported by bio-physical and economic model-based assessments, may face important barriers in their implementation driven by the socio-institutional context. Identifying climate change adaptation barriers and their causes can support decision-makers in planning adaptation processes as it provides a more realistic picture of the effectiveness and feasibility of adaptation strategies and allows for the development of actions to overcome obstacles to adaptation.

Acknowledgements The authors would like to acknowledge the stakeholders and experts involved in the participatory process and validation of results, and those scientists, especially Dr. Sukaina Bharwani, that provided valuable comments.

Funding information This research was funded by the European Commission through the MEDIATION project (Methodology for Effective Decision-Making on Impacts and Adaptation FP7, Small Collaborative Project, European Commission, DG Research, Project No. 244012, 2010–2013), and co-funded by Universidad Politécnica de Madrid through a PhD scholarship of UPM R&D Programme.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Open Access This article is distributed under the terms of the Creative Commons Attribution 4.0 International License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made.

References

- Adger WN (2003) Social capital, collective action, and adaptation to climate change. *Econ Geogr* 79:387–404. <https://doi.org/10.1111/j.1944-8287.2003.tb00220.x>
- Adger WN, Dessai S, Goulden M, Hulme M, Lorenzoni I, Nelson DR, Naess LO, Wolf J, Wreford A (2009) Are there social limits to adaptation to climate change? *Clim Chang* 93:335–354. <https://doi.org/10.1007/s10584-008-9520-z>
- Agrawal A (2010) Local institutions and adaptation to climate change. In: Mearns R, Norton A (eds) *Social dimensions of climate change: equity and vulnerability in a warming world*. The World Bank, Washington DC, pp 173–197
- Albiac J, Tapia J, Meyer A, Hanemann M, Mema M, Calatrava J, Uche J, Calvo E (2008) Los problemas económicos de la planificación hidrológica. *Revista de Economía Aplicada* 47:25–50
- Albizua A, Zografos C (2014) A values-based approach to vulnerability and adaptation to climate change. Applying Q methodology in the Ebro Delta, Spain. *Env Pol Gov* 24:405–422. <https://doi.org/10.1002/eet.1658>
- Barnett J, Evans LS, Gross C, Kiem AS, Kingsford RT, Palutikof JP, Pickering CM, Smithers SG (2015) From barriers to limits to climate change adaptation: path dependency and the speed of change. *Ecol Soc* 20:5. <https://doi.org/10.5751/ES-07698-200305>
- Bates BC, Kundzewicz ZW, Wu S, Palutikof JP (2008) *Climate change and water*. Technical paper of the intergovernmental panel on climate change. IPCC Secretariat, Geneva
- Berbel J, Calatrava J, Garrido A (2007) Water pricing and irrigation: a review of the European experience. In: Molle F, Berkoff J (eds), *Irrigation water pricing policy: the gap between theory and practice*. CABI, IWMI, pp 295–327
- Berbel J, Gómez-Limon C, Gutiérrez-Martín JA (2017) Modernización de regadíos y ahorro de agua. In: Berbel J, Gutiérrez-Martín C (eds) *Efectos de la modernización de regadíos en España*. Cajamar, Almería, Spain, pp 185–220

- Berkes F (2009) Evolution of co-management: role of knowledge generation, bridging organizations and social learning. *J Environ Manag* 90:1692–1702. <https://doi.org/10.1016/j.jenvman.2008.12.001>
- Bharwani S, Downing TE, Varela-Ortega C, Blanco I, Esteve P, Carmona G, Taylor R, Devisscher T, Coll Besa M, Tainio A, Ballard D, Watkiss P (2013). Social network analysis: decision support methods for adaptation, MEDIATION Project, Briefing Note 8
- Biesbroek GB, Klostermann JEM, Termeer CJAM, Kabat P (2013) On the nature of barriers to climate change adaptation. *Reg Environ Chang* 13:1119–1129. <https://doi.org/10.1007/s10113-013-0421-y>
- Blanco-Gutiérrez I, Varela-Ortega C, Flichman G (2011) Cost-effectiveness of groundwater conservation measures: a multi-level analysis with policy implications. *Agric Water Manag* 98:639–652. <https://doi.org/10.1016/j.agwat.2010.10.013>
- Bodin O, Crona BI (2009) The role of social networks in natural resource governance: what relational patterns make a difference? *Glob Environ Chang* 19:366–374. <https://doi.org/10.1016/j.gloenvcha.2009.05.002>
- CEDEX (Centro de Estudios y Experimentación de Obras Públicas) (2011) Evaluación de los impactos del cambio climático en los recursos hídricos en régimen natural. Dirección General del Agua. Ministerio de Medio Ambiente y Medio Rural y Marino
- CHG (Confederación Hidrográfica del Guadiana) (2013). Plan Hidrológico de la parte española de la Demarcación Hidrográfica del Guadiana. Spanish Ministry of Agriculture, Food and Environment Badajoz, Spain
- Dang H, Li E, Bruwer J, Nuberg I (2014) Farmers' perceptions of climate variability and barriers to adaptation: lessons learned from an exploratory study in Vietnam. *Mitig Adapt Strateg Glob Change* 19: 531–548. <https://doi.org/10.1007/s11027-012-9447-6>
- Deressa T, Hassan R, Ringler C, Alemu T, Yesuf M (2009) Determinants of farmers' choice of adaptation methods to climate change in the Nile basin of Ethiopia. *Glob Environ Chang* 19:248–255
- Downing TE (2012) Views of the frontiers in climate change adaptation economics. *WIREs Clim Chang* 3:161–170. <https://doi.org/10.1002/wcc.157>
- EC (Commission of the European Communities) (2012) River basin management plans. Report on the implementation of the Water Framework Directive. Report from the Commission to the European Parliament and the Council. COM(2012) 670 final. Brussels, Belgium
- EEA (European Environment Agency) (2012) Climate change, impacts and vulnerability in Europe 2012. An indicator based report. European Environmental Agency. EEA, Copenhagen, 2012
- Eisenack K, Moser SC, Hoffmann E, Klein RJT, Oberlack C, Pechan A, Rotter M, Termeer CJAM (2014) Explaining and overcoming barriers to climate change adaptation. *Nat Clim Chang* 4:867–872. <https://doi.org/10.1038/nclimate2350>
- Eisenack K, Stecker R (2012) A framework for analyzing climate change adaptations as actions. *Mitig Adapt Strateg Glob Change* 17:243–260. <https://doi.org/10.1007/s11027-011-9323-9>
- Engle NL (2011) Adaptive capacity and its assessment. *Glob Environ Chang* 21:647–656. <https://doi.org/10.1016/j.gloenvcha.2011.01.019>
- Esham M, Garforth C (2013) Agricultural adaptation to climate change: insights from a farming community in Sri Lanka. *Mitig Adapt Strateg Glob Change* 18:535–549. <https://doi.org/10.1007/s11027-012-9374-6>
- Esteve P, Varela-Ortega C, Blanco-Gutiérrez I, Downing TE (2015) A hydro-economic model for the assessment of climate change impacts and adaptation in irrigated agriculture. *Ecol Econ* 120:49–58. <https://doi.org/10.1016/j.ecolecon.2015.09.017>
- Fischer AP, Jasny L (2017) Capacity to adapt to environmental change: evidence from a network of organizations concerned with increasing wildfire risk. *Ecol Soc* 22:23. <https://doi.org/10.5751/ES-08867-220123>
- Folke C, Hahn T, Olsson P, Norberg J (2005) Adaptive governance of social-ecological systems. *Annu Rev Environ Resour* 30:441–473. <https://doi.org/10.1146/annurev.energy.30.050504.144511>
- Freeman LC (2004) The development of social network analysis: a study on the sociology of science. Empirical Press, Vancouver, BC Canada
- Huntjens P, Lebel L, Pahl-Wostl C, Camkin J, Schulze R, Kranz N (2012) Institutional design propositions for the governance of adaptation to climate change in the water sector. *Glob Environ Chang* 22:67–81. <https://doi.org/10.1016/j.gloenvcha.2011.09.015>
- Iglesias A, Garrote L (2015) Adaptation strategies for agricultural water management under climate change in Europe. *Agric Water Manag* 155:113–124. <https://doi.org/10.1016/j.agwat.2015.03.014>
- IPCC (2013) Summary for policymakers. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Stocker TF, Qin D, Plattner GK, Tignor M, Allen SK, Boschung J, Nauels A, Xia Y, Bex V, Midgley PM (Eds.) Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA
- Ivey JL, Smithers J, De Loe RC, Kreutzweiser RD (2004) Community capacity for adaptation to climate-induced water shortages: linking institutional complexity and local actors. *Environ Manag* 33:36–47. <https://doi.org/10.1007/s00267-003-0014-5>
- Jiménez Cisneros BE, Oki T, Arnell NW, Benito G, Cogley JG, Döll P, Jiang T, Mwakilila SS (2014) Freshwater resources. In: Climate change 2014: impacts, adaptation, and vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Field CB, Barros VR, Dokken DJ, Mach KJ, Mastrandrea MD, Bilir TE, Chatterjee M, Ebi KL, Estrada YO, Genova RC, Girma B, Kissel ES, Levy AN, MacCracken S, Mastrandrea PR, White LL (eds) Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp 229–269
- Jones L, Boyd E (2011) Exploring social barriers to adaptation: insights from western Nepal. *Glob Environ Chang* 21:1262–1274. <https://doi.org/10.1016/j.gloenvcha.2011.06.002>
- J de Extremadura (2013) Plan de adaptación al cambio climático de Extremadura. Recursos hídricos. Consejería de Agricultura, Desarrollo Rural, Medio Ambiente y Energía. Badajoz, Spain
- Krysanova V, Dickens C, Timmerman J, Varela-Ortega C, Schlüter M, Roest K, Huntjens P, Jaspers F, Buiteveld H, Moreno E, De Pedraza-Carrera J, Slámová R, Martinkova M, Blanco I, Esteve P, Pringle K, Pahl-Wostl C, Kabat P (2010) Cross-comparison of climate change adaptation strategies across large river basins in Europe, Africa and Asia. *Water Resour Manag* 24:4121–4160. <https://doi.org/10.1007/s11269-010-9650-8>
- Lienert J, Schnetzer F, Ingold K (2013) Stakeholder analysis combined with social network analysis provides fine-grained insights into water infrastructure planning processes. *J Environ Manag* 125:134–148. <https://doi.org/10.1016/j.jenvman.2013.03.052>
- López-Gunn E, Zorrilla P, Prieto F, Llamas MR (2012) Lost in translation? Water efficiency in Spanish agriculture. *Agr Water Manage* 108:83–95. <https://doi.org/10.1016/j.agwat.2012.01.005>
- Marin A, Wellman B (2011) Social network analysis: an introduction. In: Carrington P, Scott J (eds) The SAGE handbook of social network analysis. Sage, London, pp 11–25
- Measham TG, Preston BL, Smith TF, Brooke C, Gorrard R, Withycombe G, Morrison C (2011) Adapting to climate change through local municipal planning: barriers and challenges. *Mitig Adapt Strateg Glob Change* 16:889–909. <https://doi.org/10.1007/s11027-011-9301-2>
- Moser SC, Ekstrom J (2010) A framework to diagnose barriers to climate change adaptation. *PNAS* 107:22026–22031. <https://doi.org/10.1073/pnas.1007887107>
- Mukheibir P, Kuruppu N, Gero A, Herriman J (2013) Overcoming cross-scale challenges to climate change adaptation for local government:

- a focus on Australia. *Clim Chang* 121:271–283. <https://doi.org/10.1007/s10584-013-0880-7>
- Pahl-Wostl C, Knieper C (2014) The capacity of water governance to deal with the climate change adaptation challenge: using fuzzy set qualitative comparative analysis to distinguish between polycentric, fragmented and centralized regimes. *Glob Environ Chang* 29:139–154. <https://doi.org/10.1016/j.gloenvcha.2014.09.003>
- Paul C, Weinthal E, Bellemare M, Jeuland M (2016) Social capital, trust, and adaptation to climate change: evidence from rural Ethiopia. *Glob Environ Chang* 36:124–138. <https://doi.org/10.1016/j.gloenvcha.2015.12.003>
- Pelling M, High C (2005) Understanding adaptation: what can social capital offer assessments of adaptive capacity? *Glob Environ Chang* 15:308–319. <https://doi.org/10.1016/j.gloenvcha.2005.02.001>
- Pelling M, High C, Dearing J, Smith D (2008) Shadow spaces for social learning: a relational understanding of adaptive capacity to climate change within organisations. *Environ Plann A* 40:867–884. <https://doi.org/10.1068/a39148>
- Putnam R (1995) Turning in, turning out: the strange disappearance of social capital in America. *PS-Polit Sci Polit* 28:667–683. <https://doi.org/10.2307/420517>
- Scheffran J, Marmer E, Sow P (2012) Migration as a contribution to resilience and innovation in climate adaptation: social networks and co-development in Northwest Africa. *Appl Geogr* 33:119–127. <https://doi.org/10.1016/j.apgeog.2011.10.002>
- Schiffer E, Hauck J (2010) Net-map: collecting social network data and facilitating network learning through participatory influence network mapping. *Field Methods* 22:231–249. <https://doi.org/10.1177/1525822X10374798>
- Scott CA, Vicuña S, Blanco-Gutiérrez I, Meza F, Varela-Ortega C (2014) Irrigation efficiency and water-policy implications for river basin resilience. *Hydrol Earth Syst Sci* 18:1339–1348. <https://doi.org/10.5194/hess-18-1339-2014>
- Smit B, Wandel J (2006) Adaptation, adaptive capacity and vulnerability. *Glob Environ Chang* 16:282–292. <https://doi.org/10.1016/j.gloenvcha.2006.03.008>
- Stein C, Ernstson H, Barron J (2011) A social network approach to analyzing water governance: the case of the Mkindo catchment, Tanzania. *Phys Chem Earth* 36:1085–1092. <https://doi.org/10.1016/j.pce.2011.07.083>
- UNEP (United Nations Environment Programme) (2012) The UN-water status report on the application of integrated approaches to water resources management. United National Environment Programme
- Varela-Ortega C, Blanco-Gutiérrez I, Esteve P, Bharwani S, Fronzek S, Downing T (2016) How can irrigated agriculture adapt to climate change? Insights from the Guadiana Basin in Spain. *Reg Environ Chang* 16:59–70. <https://doi.org/10.1007/s10113-014-0720-y>
- Wolf J, Adger WN, Lorenzoni I, Abrahamson V, Raine R (2010) Social capital, individual responses to heat waves and climate change adaptation: an empirical study of two UK cities. *Glob Environ Chang* 20:44–52. <https://doi.org/10.1016/j.gloenvcha.2009.09.004>