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RESEARCH ARTICLE

Building socio-hydrological resilience "improving capacity for building a socio hydrological system resilience"

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Abstract

In response to the climate change, hydrologic and environmental changes and increased uncertainties, implication of water resilience in a context of water governance is essential for improved management. This study aims to answer the following questions: 1) what are different types of resilience with regard to its several definitions, 2) what is the relationship between resilience, trend and performance in water governance. This research applied literature reviews (as theoretical approach) and interviews with local water managers (as experimental approach) to develop better resilient plan under extreme events. This study compared the results of reviewed articles with results that we obtained from interviews with water managers in a case study area in order to develop a resilience planning under extreme events. The research has analyzed the resilience for water management based on theoretical and empirical knowledge and also provided some helpful recommendations for building system resilience for the future. The analysis of the findings shows that sufficient resilience in each society depends considerably on water resources planning (implied by the government) and also resilience in water supply infrastructure (designed by engineers). In addition, in order to get a high level of resilience, integration of ecological knowledge, water supplies, government's regulation/legislation, engineering projects and humans' interaction, is necessary. Moreover, the results indicate that failures and hydrologic catastrophes are mainly as a result of big gaps between these elements and also a lack of integrated approach between water-institutions and the environment in water management.

Keywords Resilience · Governance · Water supplies · Society · Hydrology · Climate change

Introduction

Within the past decades, resilience has played a significant role in global environmental research. Because resilience focuses on complexity of management, occurrences and alterations across various scales, and also the challenges in social-ecological systems globally. In regard to increasing complexity of system dynamics in a human-domain planet, or what is mentioned as the anthropogenic environmental changes, the governance is moving from organization of

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productivity and optimization, towards a system of raising capacity for alteration and adaptability to reorder and adjust (Ayyub 2014). Some aspects of resilience such as flexibility, interconnectedness, or social learning are still not sufficiently analyzed in terms of particular design, planning or authority practices in different circumstances and areas (Javadinejad et al. 2019a). Therefore, resilience considerations should be recognized as political and historical aspects in the resilience planning and strategy (Meerow et al. 2016). Currently, resilience planning contains complicated realities of environmental alteration and resource governance in particular contexts (Francis and Bekera 2014).

Amongst all natural systems, water systems are affected considerably by global environmental alterations. Previous researches such as Javadinejad et al. 2019b; Southwick et al. 2014 highlighted the multiple pressures on global water supplies, groundwater depletion, increasing flood risks and limitation in freshwater boundaries. From a water security viewpoint, the implications of these alterations are great and can be a serious threat to the economic development and humans' livelihood. To achieve a resilience water resources planning, incorporating complications and uncertainties into the decision-making processes, within water governance is necessary.

Also climate change has imposed many uncertainties as it contains many assumptions because of fluctuating natural systems (Javadinejad et al. 2020a). During the past decade variability in the hydrologic data has increased and uncertainty around projected hydrologic cycles has risen, therefore it makes a great challenge for water planners worldwide to plan for a long-term water management planning (Hosseini et al. 2016).

Because of climate change and its effects on hydrological cycle combined with rising urbanization, also pressures and governance disputes, some regions such as United Statas (US) is faced with significant problems in urban water management systems due to lack of resiliency (Iraci et al. 2016).

Global policy suggests that resilience should be established in water governance system of those regions under climate change impacts to help combat the various effects and other upcoming stresses (De Souza et al. 2015; Javadinejad et al. 2020b). Because water systems alone cannot be flexible as these are only slowly adaptable to the climate change. Also in many regions around the world, there is lack of innovative and transformative practices in the water systems management.

In addition, there are large gaps between the policy objectives in making water resilient and the scholarly and scientific assertions and evidences. Particularly, there is still lack of knowledge in future hydrologic adaptation, new hydrologic technology and also in understanding the water governance or broader behavioral or structural alterations (Javadinejad et al. 2020c).

Furthermore, there is a conceptual differences in describing resilience and the systems to apply resilience to. This is likely because of the multidisciplinary nature of the resilience and its linkages to multiple analyses that can specifically create big challenges in water sector (Javadinejad et al. 2020d).

This paper aims to analyze how resilience in theory has influenced water resources in its various features such as water governance, drought organization, flood organization, water resource management, and sanitation. This study is also to recognize which values, tools or practices are needed to take into account for water-related resilience and find out who is responsible for them and the trades off. Therefore, this paper reviewed the previous literatures and we have interviewed some water managers in a case study to identify key trends in building resilience and the actions to include in governance for improving resilience. We compared the results of reviewed articles with results that we obtained from interviews with water managers in a case study area in order to develop a resilience planning under extreme events. We have analyzed the resilience for water management based on theoretical and empirical knowledge and also provided some helpful recommendations for building system resilience for the future..

Relationship between water demand, communities, extreme events and resilience

Two of the most important extreme events are drought and flood. Drought can caused by climate change, land use change, over irrigation, or water over abstraction from surface and groundwater resources (Javadinejad et al. 2020e). Therefore, analyzing both drought dissemination and responses and the influences of climatic and social parameters in shaping the processes for resilience is necessary (Javadinejad et al. 2019h). Regarding drought, it should be analyzed in the rural and urban regions to understand which areas are affected more. The resilience process for two different regions is completely different and it depends on several factors such as: 1)For example in rural areas because the most water demand is related to the irrigation on farmlands, so resilience could be changing plantation time or changing crop types or cultivation location. 2) In urban areas because water demand depends on industrial and domestic abstractions, the resilience for control drought is based on increasing public awareness. 3) The resilience in urban areas also depends on average income, residential level, and average per capita water consumption. These socioeconomic factors are influential in building resilience and in the decision-making processes.

Regarding flood events, the resilience significantly depends on: 1) pre-monitoring and flood warning (urban or rural regions). 2) Capacity of society and people's behavior towards flood events. For example high social preparation against flood events can effect on the efficiency of flood warning systems. 3) Green society (no structural actions for decreasing

the risk of flood) and technological society (with structural actions for reducing flood risk) have different resilience levels. For example the resilience of green society significantly depends on pre-actions for reducing the flood risks including refusal to build the structure in the flood plain areas. However, the resilience of structural society depends on post-actions and performance of flood preventing structure such as dams, storages and dikes. Both green and technological society's reaction is completely depending on the memory of human society against flood events. Also, depending on a type of water or energy sectors' consumers, their culture, religion and economic condition (economic growth and sustainability), the type of resilience in a form of green or technological or combined will shape.

Resilience approaches in water resource governance, policy and institution

As mentioned in "Relationship between water demand, communities, extreme events and resilience" section the resilience is known as the capability of systems (social or biophysical) to resist or manage the risks, shocks or stresses (which can caused by climate alteration, social crises, economic shocks or catastrophic events) while continuing to maintain the certain key functions or structures (Javadinejad 2016).

Recently, resilience is considered to get expanded to address the objectives of adapting to various changes towards a more desirable states (Robins et al. 2017). In addition, resilience in recent socio-ecological systems has been developed as complex adaptive system.

In particular, according to the social sciences' evaluation, there are some problems with resilience in terms of the overly abstract and technical connotations of resilience for having the trend to disregard or excessively abridge questions of power of social dynamics (Ingalls and Stedman 2016). So, new planning strategy for resilience should include all the different domains of sciences. Because resilience in water resources need to response to the effects of climate change, so it should consider several aspects particularly social dynamics and government s' actions. The resilient actions related to water resource sector are control at urban and watershed scales, flood organization, drought/flood management, water demand; integrated water resource organization. From past to present, preventive measures, including the promotion of early warning systems and timely resilience to tackle new climate change, revising building codes to ensure the resilience of critical infrastructure such as schools, hospitals and roads, and more investments in flood defense is essential for protecting more people from disasters. We have no time to lose, because climate-related disasters continue to increase and affect millions of people (Javadinejad et al. 2019c).

There is no single description of water resilience and at current time, making resilience in the water sector is framed as contributing to develop water security in the face of climate alteration, or decrease vulnerability to water-related risks and dangers.

Developing strategies for resilience water management plan can lead to rise in flexibility of the water sector and can increase reliance on natural phenomena (such as mitigation in flood effects). It can also lead to use a new technology like green infrastructure safely and can significantly improve water supply and water quality management.

Some previous works such as Bruce et al. 2020; Javadinejad et al. 2019d mentioned that polycentric governance can make good resilience in water management; other publications such as Singh et al. 2020; Timmerman 2020 explained that decentralized forms of governance have more benefits for increasing resilience. With the different forms of governance the reaction towards a natural disaster is different (Javadinejad et al. 2018). For example, polycentric governance believed that in flood risk management, it is needed to mitigate the flood risk (it means prevent the flood event), however, decentralized forms of governance believed that adaptation with flood is more important (it means that creating strategies or using methods to capture excess water in a natural systems, such as slowing the flow and building inland reservoirs to store floodwater). So, water resilience is considerably diverse and provides many practical challenges for water managers (Javadinejad et al. 2019f).

Water resilience at global level are described by UN Water, OECD, UNDP, the World Bank, IPCC reports, the Global Water Partnership,, and The European Commission. These organizations play important roles in global water governance. Also, the resilience at local level such as in cities and hydrological systems should increase (Javadinejad et al. 2019g).

Furthermore, uncertainties in the future water cycle and probable hazards (like floods or droughts) should be established in global and local resilience strategy to improve water planning and institutions' actions.

Water management plays an important role in connecting human systems (human society) and water systems (natural society). Water management can control the resilience of both systems by institutions, policy and rules. Also, monitoring drought warning or flood events with modeling water resources the resilience cannot be simulated, which this depends on government, social and institution factors. So the planning for the resilience should include all the parameters.

Institutional organization, which their rules and standards are developed by humans to manage their conduct, may have a significant role in decreasing hesitation in a complicated, unclear circumstances. Presence of institutional organization into socio-hydrology simulation can assist to clarify fundamental procedures of social reaction into (a) rules and standards, (b) communication and institutional organization (accept against reject reactions for making resilience), and (c)

situational parameters that effect on the decision building (memory of social aspects).

Various aspects of resilience still are vague. For example, the questions of who profits from resilience, what are the suitable scales for supremacy for resilience, and how new technologies can match with resilience considering the effects of climate change and the ways of management. So, there is a need for an innovation and transformation of water management to contain new and more various actors, outside the traditional water organization departments. To make sense of the innovation and transformation of water management for building resilience, this paper has used a mixed method involving a systematic scoping review of more than 50 literatures and interviewed 30 local water managers. This study has also done statistical analysis with SPSS (especially in order to analyze the relationship between performance of resilience action considering different aspects) in the case study of Middle East, in order to expand the understanding of socio-hydrological resilience for extreme events ("Materials and methodology" section). Also, this research tries to find in which parts the city leaders and water managers (e.g. infrastructure, public behavior, municipal regulation, and financial costs) have significant concerns for establishing the resilience ("Results" section). In addition, this paper have suggested a planning strategy for developing the resilience ("Developing a planning for socio-hydrological resilience based on analyzing system operations (optimization of current routes) and infrastructure investment", "Developing a strategy for socio-hydrological resilience based on increasing practices" and "Improving a planning for socio-hydrological resilience based on educating the next generation of experts and specialists" section).

Materials and methodology

The study shows key governance discussions and features of water resilient systems by using scoping review and doing interviews with 30 local water managers. This study has also done a statistical analysis with SPSS (especially in order to analyze the relationship based on weighted method that obtained the score for the highest and lowest important factors of resilience building) between performance of resilience action considering different aspects in the case study of the Middle East. This was aimed to expand understanding of socio-hydrological resilience for extreme events. The questions for interview with water managers is based on the literature databases that applies resilience framings in the setting of water control and water supplies planning (containing drought organization, flood organization, water access, water supply, sanitation). The results from literature review and results from the local interviews with water managers about important factors that effect resilience are compared. Also, this paper discusses features of governance which can help to recognize practices and solutions for water resilience. Therefore, the general steps of the approach of this study includes:

1 Define the resilience factors for extreme events that can effect planning for resilience, based on literature reviews.
2 Describe the resilience factors for extreme events that may affect developing planning strategies for resilience, based on interviews with local water managers of Middle East.
3 Comparing the theoretical results and experimental results for understanding the key factors that really can work in developing the resilience planning for extreme events.

The detail of the research methodology is shown in Fig. 1.

Scoping review

This study used the Joanna Briggs Institute's methodology (Rotz and Fraser 2018) for scoping review in order to find answers to the study specific questions.

Scoping reviews are examining and most often applied to represent the theoretical boundaries and the extent and nature of proof on a topic (Elmhirst et al. 2017).

It can increase interdisciplinary works that can apply multidimensional theories such as resilience, sustainability, climate alteration adaptation and susceptibility, that can cross over the various literatures, methodologies, etc. (Berbés-Blázquez et al. 2016).

Analysis

This paper focused on the resilience which can be developed by appropriate water organization or governance. This paper obtained some codes for each aspect of resilience. For example, resilience against climate change, resilience against natural drought or flood and resilience against other risks and hazards. The codes can help governments to make the best resilience for the different aspects. For example the codes depend on the situation that can address specific characteristics, practices or actions that should involve stakeholder engagement and integration across governance sectors). In addition this paper uses SPSS in order to analyze the relationship between performance of resilience action with considering different aspects.

Results

Descriptions, systems, scale, purposes and features of water resilience

The results are provided based on the literature reviews and interviews that explained in "Materials and methodology"

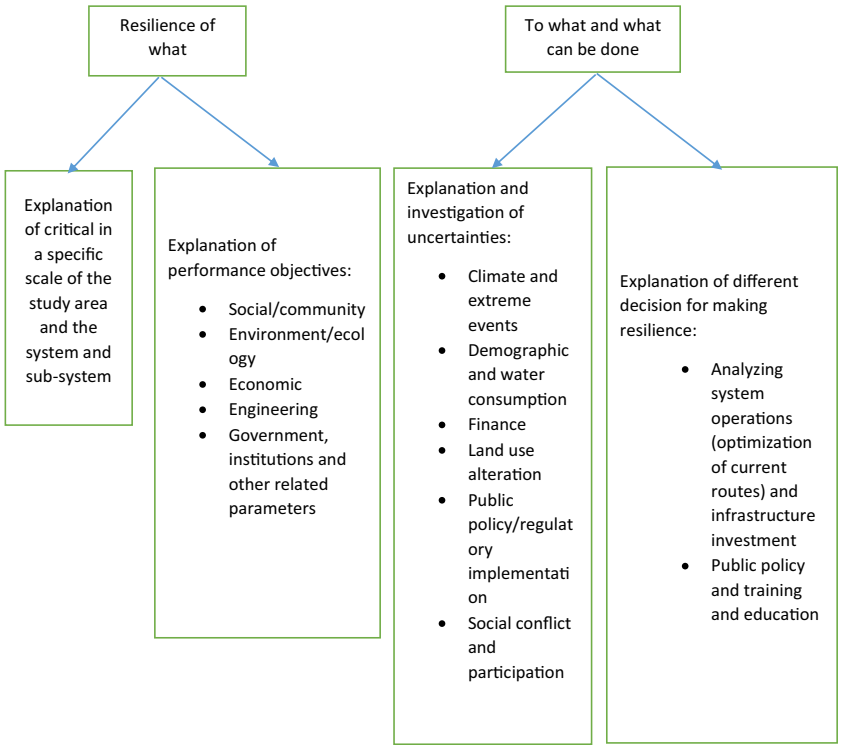

Fig. 1 Methodology of the research

section and then simulated the results with statistical analysis with SPSS.

Descriptions of resilience

This paper compared the different descriptions of resilience by reviewing previous studies. Some previous researches such as Nguyen et al. 2020; Dardonville et al. 2020 did not provide the clear descriptions of resilience.

In the description of resilience, especially in water systems, it is important to understand two main aspects in the resilience: 1) the capability of the system to return to normal situation or the capability of the system to adapt in reaction to changes or turbulences. 2) Kind of systems to which resilience is utilized to coupled different aspects such as social-ecological or green-grey infrastructure.

Description of resilience in the views of water engineering depend on particular quantifiable attributes of engineered infrastructure systems, such as reliability, recovery. However, description of resilience in eco-hydrological systems depends on the reactions of the water and social-ecological systems.

Although, the descriptions of resilience are various, however they can help to determine key trends in resilience concept. There is a cumulative graph of the different types of definitions and actions of resilience identified by different aspects during 2006–2017 (Fig. 2). Also Fig. 3 showed that the participation of different communities and institutions in building resilience. The results of Figs. 2 and 3 come from the opinion of the interviewers.

Water domains and scale

Analysis of the results for water resilience showed that majority of previous researches (61%) focused on the actions of water supply management and 39% of the researches focused on drainage and storm-water management. However, the resilience which contain sanitation and wastewater management, rarely considered in the previous researches such as Zhou et al. 2020; Hamdy et al. 2020. The review of the scale of previous resilience indicated that the most scale (77%) belongs to watershed and rivers and only 23% belongs to the city scale. The resilience actions for city and local areas (smaller communities/ watersheds regions) are different and need to be considered carefully. In addition there are very few papers (less than 2% which researched on storm water management, transboundary water management, droughts, floods).

Resilience of what (of whom) and to what?

Understanding the systems of infrastructure in building the resilience planning is very important. For example the system can be related to dams or pipes, or can be related to eco-hydrological systems like wetlands or rivers, or can be related to social systems, like communities or institutions, or can be related to hybrid systems that are combined all the systems mentioned previously.

Resilience for specific communities and for groups of consumers is different. However, previous researches such as

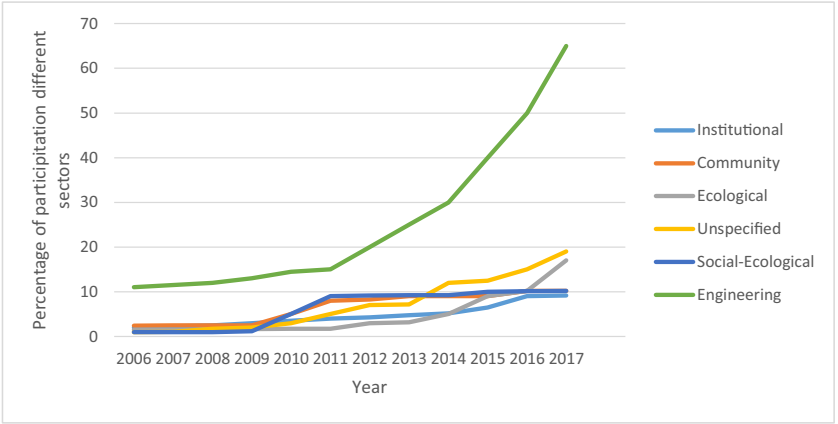

Fig. 2 Cumulative graph of the different types of definitions and actions of resilience during 2006–2017 based on literature reviews

Gleeson et al. 2019; Lawson et al. 2020 did not specify the differences.

This study with doing interview with water managers, found that making the resilience for specific communities is more important. Also this research realized that resilience for non-human systems can get lower benefits in comparison with human systems. It means that biophysical and ecological systems have lower contributions with water resilience parameters rather than social systems.

The most reason for making water resilience is climate change. Because climate change creates water stresses (about 78%), and socio-economic and political stresses (about 22%).

Characteristics of water resilient systems

Table 1 is provided in order to obtain features of water resilience systems in terms of general design characteristics, biophysical characteristics and social system characteristics (each value in the table is individual and is coming from the opinion of interviewers). The aspects of social, natural or built/engineered systems, adaptive, interconnected and flexible systems and practices, including governance that are important for building resilience are presented in the Table 1 which its data is based on previous studies. For making a proper resilience, integration between different aspects is needed. Therefore, interconnectivity between water companies to work together on a local or regional scale can improve the resilience.

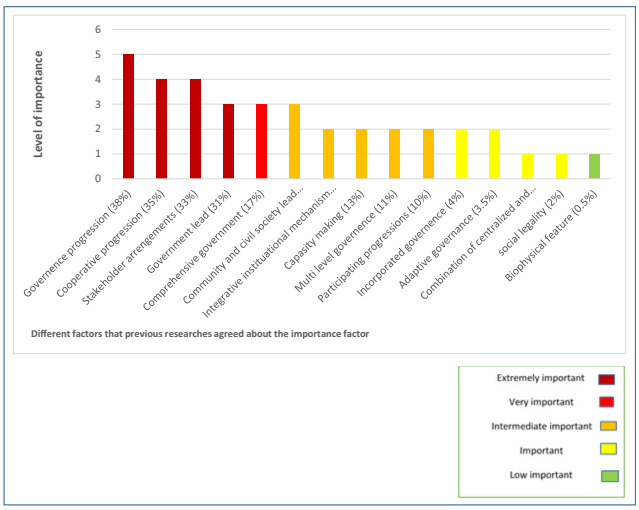

Fig. 3 Different importance of parameters relating to building resilience based on literature reviews. (The most important factor is shown at level 5 and the lowest important parameter is displayed by 0.)

For making resilience planning, considering abilities of systems to adapt and transform is more important in comparison with abilities of systems to withstand and persist.

The results of this study showed that several governance characteristics include polycentric, decentralized or having a combination of centralized and decentralized structures have important roles on the resilience planning.

Overall, adaptability, suppleness and connectivity across scales and sectors are very important features of resilient for water systems. Consideration of all various dimensions of water resilience needs to address in future works.

Table 2 shows the importance of each factor in making resilience that reached from the previous researches. As it is shown the governance progressions play the significant factor for making the resilience. Also, Fig. 3 shows the different importance of parameters relating to building resilience based on literature reviews.

Institutional, authority and applied aspects of water resilience

In this section, governance and institutional processes for building resilience are explained in Table 2. Most of the previous researches such as González 2020; Oates et al. 2020 only focused on improving resilience by technological solutions rather than improving institutional and governance aspects.

Table 1 Features of water resilient systems based on literature reviews

Classification	System features	%
Biophysical features	Strong	10
	Having idleness	3
	Capable to recover rapidly	1.1
	Having buffer capacity	0.3
	Having various functional systems	0.1
Social features	Cooperative with governance progressions	38
	Containing social learning	17
	Decentered	16.5
	Contributing	15.5
	Containing diverse information	11
	Able to deal with uncertainty	4
	Equitable	3.5
	Practical	2
	Reasonable	2
	Transparent	1
Overall system properties (can apply to systems of social, built or ecological)	Adaptive	37
	Intersected	33
	Flexible	31
	Having variety	13
	Transformative	13

This study analyzed to understand who is normally tasked with resilience building and which institutional or governance processes are very important for building resilience. As shown in Fig. 3 the results from the interview with water managers indicated that stakeholders engagement in resilience is about 92% and government engagement in resilience is about 20%. However, still stakeholders have not enough knowledge about the resilience and there is a weak collaboration between water stakeholders especially during the climate change phenomena. In addition, social acceptance for the role of stakeholders for improving resilience is very important and need to be considered carefully. Because stakeholders in most of the areas have important role in later stages of resilience-building, as well as in the beginning of plans and strategic decision-making. However, decision spaces should be opened up for more diverse input at earlier stages in developed areas.

The result of this study that collected data from previous works showed that governmental managers (who are responsible for planning water supplies), stakeholders and water-related institutions have the most important role in water resilience and then operators, people who run facilities have the second important role in water resilience in great scale (Fig. 4). However, in small scale, local governments and water managers are conventional actors for building water resilience.

Also Table 3 shows the importance of different parameters for making resilience, and the value comes from the opinions of interviewees.

This cumulative graph in Fig. 3 shows the main actors that are involved or assumed as responsible for building water resilience, which are shown in order from highest to lowest frequency. The most common actors are water managers, governments/institutions, and multiple stakeholders (often not specified which ones).

In terms of organization practices in the water sector, a great amount of water resilience is related to managing resilience at the supply side as opposed to the demand side. The strategies should start at smaller/micro-scales and then the strategies should improve for greater scales.

The role of consumers and the forms of their resistance to manage resilience by doing flexible adaptation are very important. However, there is a risk in forms of flexible and adaptive for building resilience. So, in order to reach the proper resilience, suitable strategy, appropriate integrative and proper adaptations in water systems are necessary. Also sometimes to achieve resilience, a regime in a region need to change its policies. For example in UK, future water strategy are anticipated, in order to understand whether water management regime changes will be compulsory in the future.

Also Fig. 5 shows the importance level of different parameters in building resilience. The most important factor is

Table 2 Importance factors that can improve resilience based on literature reviews

Across what governance institutional progressions is resilience reached?	Details/instances	%
Unspecified	The works that did not deliberate or specify any institutional or governance progressions as essential or important for making resilience.	38
Cooperative progressions	collaborative watershed governance, containing coordination among watershed groups, institutions and agencies at several governance scales, and policy makers as significant for making resilience.	37
Stakeholder arrangement	cooperation, coordination, and consideration among several stakeholders across scales is serious for adaptive and resilient water governance.	33
New cross-sectorial institutions/-activities	resilience in the context of water-sensitive urban design and emphasize the requisite for novel programs or alliances at the municipal level that cross beyond traditional water departments and institutions to be capable to address composite and interrelated tasks.	31
Comprehensive governance	It is one of the characteristics of adaptive resilient water control is various and descriptive contribution, cooperation, and consideration.	17
Community and civil society-led	resilience building to alterations in freshwater in rural Alaska as a community exertion, stressing community decision-making progressions and strong social connections as central to rise social resilience.	16.5
Obvious governance	analytic consideration (i.e., well-structured dialogue containing scientists, supply consumers, and attentive publics, and informed through analysis of significant information about environmental and human environment systems) as a way to address the essential for comprehensive and integrative institutional mechanisms for the obvious and evidence-based negotiation of trade-offs between stakeholders in the water governance progression for resilience.	15.5
Capacity making	Both institutional and local capability building as significant for resilience of trans-boundary treaties in given area	13
Multi-level governance	It is coordination in decision-making among national, provincial and local governments	11
Participating progressions	the conversation of information and input that happens at a time and place convenient to local citizen volunteers—is significant for institutional resilience.	10
Incorporated governance	incorporation and open communication among the various actors or agencies	4
Adaptive governance	resilience to re-conceptualize water law as a composite adaptive system legal agendas must be more adaptive and flexible to meet novel and diverse disputes.	3.5
Combination of centralized and decentralized progressions	Significant insights regarding the requirement for a combination of centralized and decentralized, and formal and informal, governance methods to sustain valuable governance of water organization throughout various stages of adjusting to drought and transitioning to a water sensitive city that is resilient to instant and gradual alteration.	3
Social legality	social legitimacy (public recognition of governmental action) as a big gap in rational about social resilience.	2
	Decisions about whether to apply adaptive organization, what to monitor, and how to make incremental adjustment should be made in a manner that promotes legitimacy.	
*Biophysical features	Capable to recover rapidly or having various functional systems	0.5

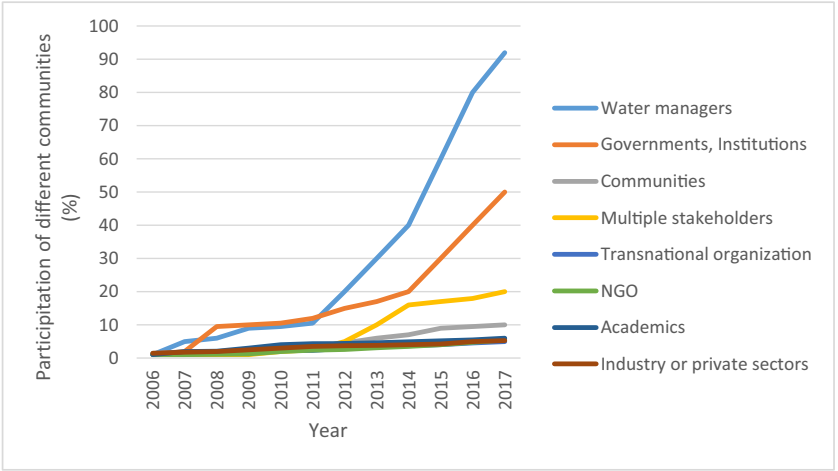

Fig. 4 Participation of different communities and institution in building resilience

defined by 5 and the lowest important parameter is displayed by 0. As it is shown the highest important factor belongs to the governance progression that explained in Table 2 and the lowest important factor belongs to the social legality.

Comparison the results of Figs. 4 and 6 can show that the most important factors for developing a planning for resilience are governance progressive, cooperative progression, stakeholder arrangements, government lead, institutional activities, comprehensive government, community and civil society lead.

Developing a planning for socio-hydrological resilience based on analyzing system operations (optimization of current routes) and infrastructure investment

In order to make the better resilience, analyzing the water system operations and water demands are necessary. As we mentioned before, depending on the study area, conditions and purpose of building resilience, analyzing the requirements for building technological and green infrastructure is essential. Investment for technological infrastructure includes: cost for making artificial recharge, maintenance for a new water resource, agriculture modernization, wastewater treatment and reuse. Investment for green infrastructure include: natural recharge of aquifer, rainwater harvesting, and reforestation.

Developing a strategy for socio-hydrological resilience based on increasing practices

In order to increase the efficiency of making the resilience planning and decrease the uncertainty and sensitivity of the system, it is important to practice the resilience more and more in short terms even in the absence of extreme events. So, it can make better integration between communities, society, stakeholders, water managers, engineering and sociologist during the extreme events.

Traditional resilience was based on the assumptions of human actions and water components. Therefore, inadequate identification of the complicated and adaptive nature of combined human and water systems may fail to provide preferred management objectives and suitable resilience. Because of some long-term reactions among humans and water systems was not fully successful. So, applying, practicing and extending socio-hydrology parameters into water supplies organization might be significantly valuable. Also, this practice may assist researchers to recognize system limitations (in simulating) and real-world difficulties to undertake the effective research. This practice can cause more participation among the socio-hydrology and water supplies organization communities.

In addition, with this practice water managers can organize much better the relationship between water resources and food security, economics, energy, biodiversity.

Improving a planning for socio-hydrological resilience based on educating the next generation of experts and specialists

Future education and practitioners with more training may result in developing communication skills to facilitate interdisciplinary collaboration. With training, the next generation of experts and specialists, can better understand in which level individual surveyors must be trained in the skill for preparing collaboration with water stakeholders and water managers.

Different strategic skills can be suggested in order to improve approaches in data science, complicated systems science, combined human and natural systems simulating, and causal extrapolation. In addition with developing skills in science, interaction training cooperation with policymakers, water managers, and the broader public can increase significantly.

Table 3 Institutional and governance features and practices that can rise resilience

Across what governance institutional progressions is resilience reached?	Details/instances	%
Unspecified	The works that did not deliberate or specify any institutional or governance progressions as essential or important for making resilience.	58
Cooperative progressions	collaborative watershed governance, containing coordination among watershed groups, institutions and agencies at several governance scales, and policy makers as significant for making resilience.	25
Stakeholder arrangement	cooperation, coordination, and consideration among several stakeholders across scales is serious for adaptive and resilient water governance.	21
Government-led	a case of making resilience to water scarcity in specific area as an institutional and regulatory effort, i.e., resilience can be improved over government-led policy and incentives.	16.5
*New cross-sectorial institutions/activities	resilience in the context of water-sensitive urban design and emphasize the requisite for novel programs or alliances at the municipal level that cross beyond traditional water departments and institutions to be capable to address composite and interrelated tasks.	11
Comprehensive governance	It is one of the characteristics of adaptive resilient water control is various and descriptive contribution, cooperation, and consideration.	9
Community and civil society-led	resilience building to alterations in freshwater in rural Alaska as a community exertion, stressing community decision-making progressions and strong social connections as central to rise social resilience.	7
*Equity	lack of equity as a obstacle to community-scale social resilience in many areas, presumably implying that equity empowers or strengthens social resilience.	3
Obvious governance	analytic consideration (i.e., well-structured dialogue containing scientists, supply consumers, and attentive publics, and informed through analysis of significant information about environmental and human environment systems) as a way to address the essential for comprehensive and integrative institutional mechanisms for the obvious and evidence-based negotiation of trade-offs between stakeholders in the water governance progression for resilience.	3
Capacity making	Both institutional and local capability building as significant for resilience of trans-boundary treaties in given area	2.5
Multi-level governance	It is coordination in decision-making among national, provincial and local governments	2.1
Participating progressions	the conversation of information and input that happens at a time and place convenient to local citizen volunteers—is significant for institutional resilience.	2.1
Incorporated governance	incorporation and open communication among the various actors or agencies	1.5
Adaptive governance	resilience to re-conceptualize water law as a composite adaptive system legal agendas must be more adaptive and flexible to meet novel and diverse disputes.	1.5
*Responsibility	The means of resilience in urban water systems and highlight responsibility (and mainly developed responsibility in urban water systems) as an empowering element of socioeconomic resilience as it aids builds trust and enhance human agency and so enable more easily transition progressions towards water sensitive cities.	0.9
Combination of centralized and decentralized progressions	Significant insights regarding the requirement for a combination of centralized and decentralized, and formal and informal, governance methods to sustain valuable governance of water organization throughout various stages of adjusting to drought and transitioning to a water sensitive city that is resilient to instant and gradual alteration.	0.9
Social legality	social legitimacy (public recognition of governmental action) as a big gap in rational about social resilience. Decisions about whether to apply adaptive organization, what to monitor, and how to make incremental adjustment should be made in a manner that promotes legitimacy.	0.9

Discussion

Overall, the impact and application of resilience in previous researches such as Ahmad et al. 2020; Foster et al. 2020 remained unclear. Nevertheless, some previous works tried to improve the consideration of resilience. For example the previous researches tried to answer the questions of why resilience is needed in several natural systems (Adil and Ko 2016).

Nevertheless, there are few works that illuminated what is resilience in system of water and distinct what novel tools and performs are essential in water resilience. Still there is a gap to recognize theoretical or empirical delineations of features of resilience in water systems. The gap related to the nature of the water sector and complication of water supply, flood organization and further aspects of water being dealt with through several disciplines (Herrera et al. 2016).

Previous researches such as Krueger et al. 2020; Shrestha et al. 2020 highlighted the important of resilience,

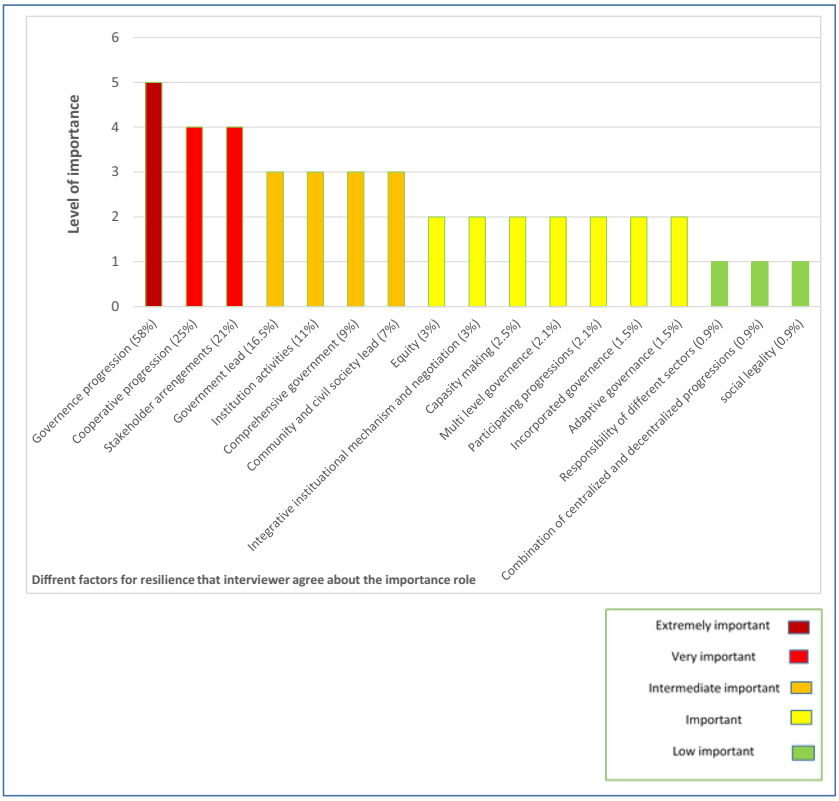

Fig. 5 Different importance of parameters relating to building resilience (The most important factor is shown at level 5 and the lowest important parameter is displayed by 0)

nevertheless, socio-political and government activities for building resilience have not been considered. Nonetheless the proper resilience should have connections withparameters of hydrological, climatic, social behaviour, politics, values, and economics embedded in socio-ecological systems. Also for building water resilience, considering effects of urbanization and request for hydrological services from humans and nature, altering behaviours and habits are necessary. Therefore, more theoretical innovation strategies are needed to provide water resilience (Caldeira et al. 2015).

In addition, depending on the circumstances of rural and urban zones, the potential for resilience is various. Also centralized versus decentralized arrangements of governments in terms of innovation practices in water management in building water resilience is very important. This could lead how water organization should be developed at the rural or urban level. Centralized or decentralized actions depend on which of them are more likely to contribute to increased resiliency (Grote 2016).

However, centralized regimes implement superior since decisions taken through national authorities may equalize access for all water consumers to sufficient levels of water and financial supplies (Chelleri et al. 2015).

One of the innovative practices for making resilience, is making flexible and technical/green infrastructure might be very challenging in rural and urban districts and it must be consider that where there is significant competition or even conflict over land (Meerow and Newell 2017) and (Konar et al. 2016).

Furthermore, adaptive governance is a main emerging perception in the water resilience. Adaptive governance can describe as moving "from a concentration on proficiency and lack of overlap amongst jurisdictional authorities to a concentration on variety, redundancy, and several levels of institute that contain local awareness and local action (Mirza and Mustafa 2016).

A research on Columbia River Basin treaty represented that if stakeholders pursue a more resilient form of river governance. It will require an alteration in the operations and performance of water allocation treaties in order to permit more flexible reaction at the international level and bigger local input and organization on attempts to restore ecosystem health, highlighting flexibility as a significant feature of resilient water control (Rodina et al. 2017).

Social contribution and justice in relation to water resilience should consider wisely. For instance, Jobbins et al. (2016) maintained that lack of equity might be a significant barrier to social resilience to droughts, principally as rising resilience to droughts is fundamentally a question of reconfiguration of water resource dispersal.

Public participation plays a significant role in developing resilience, particularly for natural risk management

(i.e. flood risk management). Effective public participation might aid to build trust between public and the professionals; thus lead to incorporation on several levels and scales. It is important to seriously assess what and how practices through public participation can be adopted (Chesterfield et al. 2016).

Water resilience should push towards theoretical and philosophical novelty to re-imagine water systems as composite socio-eco-technological systems, driven through nonlinear dynamics and unpredictable behaviour (Varady et al. 2016).

Therefore this research tries to fill the gaps that mentioned previously in the studies. This research illuminated the various ways (from social to biophysical aspects) that can be applied in several systems of water to combat multiple risks. This research highlighted that for building resilience, corporation amongst all factors of system of water dynamics during intensive happenings is necessary. Therefore, strong connection between socio-ecological and water engineering plays significant role. Another important parameter in resilience related to persistence of disciplinary in a society. Water engineers have to participate in the procedure of persistence of disciplinary in a society. A significant limitation is unconnected performance of technical system and socio-ecological parameters that impact water resilience.

Multiple disciplines like ecology-social management, engineering system, institutional management should describe resilience strategies. As the results showed in the case study of Middle East, the highest important sector in resilience is the governance progression (58%) and the lowest important factor belongs to the social legality (0.9%). In addition, improving a strategy for making a better resilience depends on: 1) Analyzing system operations (optimization of current routes) and infrastructure investment, 2) increasing practices, 3) improving a planning for socio-hydrological resilience based on educating the next generation of experts and specialists which was explained in the "Developing a planning for socio-hydrological resilience based on analyzing system operations (optimization of current routes) and infrastructure investment", "Developing a strategy for socio-hydrological resilience based on increasing practices" and "Improving a planning for socio-hydrological resilience based on educating the next generation of experts and specialists" section.

The results and findings of this study for improving the socio-hydrological resilience can be applied for other societies around the world.

Conclusions

The analysis based on previous works and literatures and interviews with water managers in a case study area in Middle East indicated that while many previous works on water resilience tends to concentrate primarily on constructing infrastructural resilience, there remains relatively fractured recognizing the elements, practices, and governance principles that aid growth the resilience of people, communities, or society at large to water-related risks..

Governance dimensions, stakeholder engagement and contribution can play significant role for securing social acceptance; nevertheless, the responsibility for resilience making stays mainly in the hands of governments and water managers.

Finally, since there are a few works on adaptive and polycentric governance and there are small works on applying water-sensitive values in water planning, there is yet little evidence for novelty or transformation in the water sector towards climate sensitive and equitable water governance.

This research indicated innovative approaches to water resilience, which however are likely to rise in the coming decades as new policy plans and approaches come alive. So this research showed the challenges modes of governance and considered possibilities for making resiliencies in the water sector.

The resilience suggestions related to engineered systems, ecosystems management and urban water planning and governance. The countries tried to make theoretical bridge of engineering and ecological notions of resilience in the water sector.

In general the results of this paper indicated that under the disaster phenomena, multiple disciplines like ecology-social management, engineering system, institutional management should have a role in planning strategies for resilience. As results showed in the case study of Middle East, the highest important sector for making resilience belongs to the governance progression and the lowest important factor belongs to the social legality.

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Authors' contributions Safieh Javadinejad designed this research and she wrote this paper and she collected the necessary data and she did analysis of the data.

Rebwar Dara and Forough Jafary participated in drafted the manuscript and he contributed in the collection of data and interpretation of data and edited the format of the paper under the manuscript style.

Compliance with ethical standards

Conflict interests The authors declare that they have no competing interests.

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