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Assessing water security in Central Asia through a Delphi method and a clustering analysis

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The accessibility to freshwater sources and even allocation among different uses has become one of the most challenging sustainability aspects, especially in developing and transition economies, where a rapid increase in water consumption and poor management practices are more frequent. Water security has been adopted as a relatively new concept to encompass the relevant dimensions for the sustainable management of freshwater resources. Still, water security remains a rather abstract notion without well-established and measurable indicators. Central Asia (CA) is a region where water security was prioritized after the Soviet dissolution in 1991; however, several socio-economic, environmental, and transboundary aspects hinder establishing a common understanding. In this study, we have attempted to synopsize the concept of water security in CA as perceived by the views of water professionals with experience and expertise in the region. We applied a Delphi method and analyzed its outcome with clustering and regression analysis to better comprehend the agreement rate among water professionals on critical aspects of water security in the CA region. Our devised methodology can quantify the general agreement rate among professionals and assess the behavioural trends for iterative Delphi rounds. The findings suggest that the economic dimension of water security in CA is the ultimate priority for nearly all water professionals, while the national priorities for each CA county are not identical. The study anticipates identifying the elements needed for a commonly agreed water security framework in CA and offering methodological insights for the assessment of socio-ecological challenges.

KEYWORDS

water professionals, transboundary water systems, agreement rate, variability and distance matrix, Central Asia

Introduction

The concept of water security has gained increasing importance due to the uncertainties of the climate crisis and rising water demand (GWP, 2000; UN Security, 2007; OECD, 2013; IPCC, 2021). Several interpretations have been introduced for water security by scholars and practitioners, which commonly underline the multidimensional and versatile aspects of the security notion (Cook and Bakker, 2012; Gerlak et al., 2018; Xenarios et al., 2020). The definition of water security could be broadly interpreted through physical and social dimensions as is indicated by the UN-Water: "*the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stabilit*"' (UN Water, 2013, p.1). Still, the conceptualization of water security remains broad and varies because of "*institutional agendas, objectives, disciplinary approaches, theoretical leanings, political preferences, views of justice and equity and geographic settings*" (Gerlak et al., 2018, p.86).

Various metrics and frameworks have been developed to assess water security from multiple perspectives and scales (AWDO 2013; OECD, 2013; Gain et al., 2016; AWDO 2016; AWDO 2020; Octavianti, 2020). One of the comprehensive water security assessments was conducted by the Asian Development Bank, introducing a framework (Asian Water Development Outlook-AWDO) to capture the most distinguished parameters (dimensions) affecting water security in Asia and the Pacific. Five dimensions were highlighted: household, urban, environmental, economic, and resilience to water-related disasters. The AWDO framework was qualitatively assessed through measurable indicators within an approximate 3-year interval (AWDO 2013; AWDO 2016; AWDO 2020). This framework was also applied and adjusted for particular countries and regions, including South Africa (Holmatov et al., 2017), China (Sun et al., 2016), Egypt (Gaber et al., 2021), and CA (Xenarios et al., 2020).

Despite the efforts to assess water security, the institutional and socio-ecological parameters on a country and regional level could challenge any evaluation attempt, as pointed out in many studies published in the recently established Water Security journal. The transboundary features of freshwater systems add to the complexity of the water security definition. The conceptualization and assessment of water security on transboundary river basins has often become arduous, requiring context-specific approaches in consultation with relevant stakeholders (Babel and Shinde, 2018).

CA is a typical example of commonly used transboundary river systems, interconnected irrigation and hydropower infrastructure, and uneven water allocation. Transboundary water resources in CA are vital for ensuring the entire region's food, energy, and environmental sustainability (Chan, 2010; Granit et al., 2012; Sehring, 2020). CA is also characterized by the Soviet past, where water security was interpreted through water engineering infrastructure for irrigated cotton production in downstream republics (Kazakhstan, Turkmenistan, Uzbekistan) and partially for water storage and hydropower generation in upstream republics (Kyrgyzstan and Tajikistan). The two large basins of Amudarya and Syrdarya rivers (Figure 1), together with several tributaries, were heavily exploited in the Soviet era and, combined with water mismanagement practices, contributed to the Aral Sea desiccation, an emblematic disaster with significant consequences for the entire region (Abdullaev et al., 2019; Peterson, 2019; Wheeler, 2021). In our study, we also included the country of Afghanistan due to the extensive sharing of the Amudarya river with Tajikistan in the upstream region.

In the aftermath of the Soviet Union's dissolution, the independent states inherited extensive hydro-technical infrastructure, which they could hardly sustain with limited national budgets. The urgent need of all CA countries to reform their socio-economic systems set aside the prioritization of water resource management and planning by also downgrading the intra-regional cooperation (Cassara et al., 2019). Also, the dissolution of the Soviet Union brought some new realities for water security by accentuating the national priorities for each CA country (Granit et al., 2012; Abdullaev et al., 2019; Xenarios et al., 2019a). The upstream countries, deprived of considerable energy resources, perceive water resources as a leverage to increase hydropower use and tackle energy sufficiency, especially in winter. The downstream countries endowed with hydrocarbon reserves require agricultural water supply for sufficient food production. The extensive water usage for agriculture in arid and semi-arid regions, the population growth and urbanization, the water-intensive mining activities, and glacial melting in mountainous areas in the Pamirs and Tien-Shan ranges in southeast CA, have exacerbated water security challenges in the region (Hoelzle et al., 2019).

A bibliometric review was recently conducted to analyze the definition of water security in CA and the regional and national priorities identified for the period 1990–2019 (Xenarios et al., 2020). The study revealed that water security in CA is primarily interpreted through technical and infrastructural approaches to protect livelihoods against climate change and weather extremes and promote economic growth; in contrast, water policy and governance are overlooked. However, there is a vacuum in the perceptions of water professionals, directly and indirectly, involved in water policy reforms in CA (Assubayeva et al., 2021). Water security perceptions can differ according to personal beliefs, values, knowledge, background, and professional experience (Lagerspetz, 2008). The discrepancy between water security perceptions could be elevated in the case of different priorities and needs in transboundary river basins, as occurs in the CA region. The recent conflicts

FIGURE 1
Map of Central Asia and the Aral Sea basin, Source: Adelphi and CAREC (2017).

between local communities in Kyrgyzstan and Tajikistan for disputed water supply facilities manifest the discrepancies in water security perceptions within the CA region (Radio Free Europe, 2022).

This study attempted to comprehend better water security dimensions, trends, and national priorities as perceived by water professionals with experience and expertise in the region. Furthermore, the consensus dynamics among professionals and potential drivers motivating their perceptions were explored. It is noted that we did not explore the views of local communities on water security as it would request extensive field trip research, which was beyond the scope of this study. We, however, identified similarities and differences between the findings of the bibliometric review on water security (Xenarios et al., 2020) and the perceptions of water professionals. The outcome of the bibliometric review shows that scholars prioritized the environmental dimension while water professionals ranked the economic dimension as the most important facet of water security in CA.

We assessed the water security dimensions associated with urban and household facilities, economic activities, environmental aspects, and natural hazards by adopting elements from the AWDO framework, while different attributes related to each dimension were also developed. Clustering analysis was conducted to reveal behavioural patterns of respondents towards water security dimensions in CA by assessing similarities and dissimilarities among different socio-demographic features of the participants. Further, we employed multinomial logistic regression (MNL) to detect the potential relation of respondents' profiles with the findings.

The findings indicate a consensus of professionals on the economic interpretation of water security, presented through hydro-technical and engineering interventions in the water systems of CA. There is a difference between the bibliometric review and water professionals on the water security prioritization, which can probably be attributed to the research versus the practical orientations of the professionals. The national priorities vary from country to country, leading to the planning and realization of different initiatives that may conflict. There are significant concerns about the effectiveness of the current regional mechanisms to coordinate water policies in CA by proposing significant reforms and restructuring existing

institutions. The clustering analysis and MNL provide insight into the behavioural aspects of different groups of respondents by depicting the consensus rate among the groups in a more detailed manner.

Methodology

Design of the Delphi method

The Delphi method was adopted in this study to elicit the views of water professionals on water security in CA and the national priorities for each country. The Delphi method is a structured communication technique using several survey rounds to reach a consensus or identify dissensus among panel members on areas with high uncertainties and lack of information (Birko et al., 2015; Avella, 2016). Studies employing the Delphi method attempt to reach a common understanding of complex issues, examine literature review findings and facilitate scenario planning and forecasting (De Loe et al., 2016; Belton et al., 2019). The Delphi method is based on judgmental analysis of collective knowledge for developing indices and indicators but also for validating specific findings (Chan and Lee, 2019; Chan, 2022). The Delphi approach has been widely applied as an experts' communication technique to reach an agreement on specific topics in medicine (Beattie and Mackway-Jones, 2004), education (Calabor et al., 2019), environmental sciences including water resources (Birko et al., 2015), among others. The reason for choosing Delphi in our study instead of other participatory and consensus approaches, such as citizen juries or focus groups, was as follows: 1) to engage a large group of water professionals from within and outside of the CA region 2) to be able to apply appropriate quantitative methodologies for estimating consensus within as well as between groups across Delphi rounds, and 3) to explore whether the professionals' opinions concur with the findings of our prior bibliometric analysis.

We conducted two survey rounds using the Delphi method designed with Qualtrics software in June-October 2020. Potential respondents with experience in water resources management in the CA region were identified through professional organization listings, participants in regional and international events (seminars/workshops/conferences), research and media articles. The suggested respondents came from various professional and educational backgrounds in hydraulic engineering, agricultural water management, climate change and hydrology, environmental conservation, hazards management, water policy and economics, water governance, and public policy and administration. Most of the suggested respondents had professional experience in river basin management, especially in transboundary basins, which are prevalent in the CA region. It is noted that the questionnaire in the Delphi rounds referred to the educational level and the years of experience without specifying the expertise of each respondent. We believe that working with experts with diverse backgrounds in riverine ecosystem conservation, fluvial geomorphology, natural resources management, community engagement, and other subsistence livelihood aspects could have enriched this work. However, with an objective of in-depth analysis of water resources management in the context of CA, the exercise was largely conducted with experts with apparent water resources backgrounds. There was an effort to invite respondents from CA countries but also other country origins to better capture the perceptions of regional and international professionals.

The questions for the Delphi survey on water security dimensions and water security priorities for CA countries and Afghanistan were inspired by the findings of the bibliometric review of Xenarios et al. (2020), synthesizing 151 research articles on water security aspects in CA. The bibliometric study has assessed several frameworks to better classify the research articles as per different water security dimensions. Frameworks focusing on governance, hydrology and livelihoods (OECD, 2015; GIZ, 2017), economic development and ecosystems (Lausevic et al., 2016), water management techniques (Bertule et al., 2017) and hydro-economic approaches (IIASA, 2015) were reviewed. More emphasis was given to the Asian Water Development Outlook (AWDO), which has been implemented in three consecutive rounds (2013, 2016, 2020) through measurable indicators in Asia, including the CA region. The security dimensions to be reviewed through the Delphi rounds by the water professionals mainly reflected the AWDO (2016) framework with some adjustments to the CA context. These were the dimensions associated with the urban and household facilities, economic activities, environmental aspects, and natural hazards. The urban and household water security dimension covers measures to improve water supply and sanitation access, invest in wastewater management, and implement SDG 6 (Clean Water and Sanitation). The economic water security dimension assesses whether adequate water quantity and quality are sustainably provided for economic growth, including agriculture, energy and industry. The environmental water security dimension addresses challenges linked with the health of river basin management, conservation of lakes, groundwater, and environmental ecosystems in the mountains. Lastly, the water-related hazards dimension evaluates the risks and vulnerability of water-related disasters: droughts, floods, landslides, and avalanches. Accordingly, each water security dimension consists of factors (attributes) influencing the relevant dimension (Table 2). The survey also enabled respondents to suggest other dimensions and attributes that may be considered relevant to water security challenges in the CA region.

The first survey round explored the rate of agreement of water professionals on the research findings of the bibliometric review in the following five sections: prioritization of water security dimensions (1) and related aspects (attributes) in CA

(2); historical trends and implications on a policy level (3); national priorities for each country (4); effectiveness of mechanisms dealing with regional water security issues (5). The participants were asked to rate the above sections in the context of CA from 1 to 10 (in ascending order). Based on these ratings, an average agreement rate was calculated by summing participants' ratings, divided by their number and converted to percentages. In the second round, respondents were asked to agree or disagree with the findings of the first round by exploring whether a higher agreement rate or consensus could be achieved among the respondents. Both rounds also acquired socio-demographic data to outline the respondent's background. The questionnaires of both rounds are attached in Annex A.

Clustering and statistical techniques

We employed descriptive and inferential statistics and clustering techniques to assess the homogeneity among water professionals on the water security concept in CA and identify some socio-demographic features that might shape their perceptions. The descriptive statistics were used to comprehend the respondents' background regarding their socio-demographic characteristics such as gender, age, education, citizenship, residence, native language (Russian or English), employment, and experience in the water sector. We categorized the socio-demographic data into different groups to allocate the respondents according to their profiles. For example, the age category was split into three groups: 18–34, 35–54, and 55 or older, while education was divided into two categories, namely respondents holding up to a bachelor's degree and others with postgraduate studies. The experience category was grouped according to the years of professional expertise: beginners (1–5 years), experienced (6–15 years), and highly experienced (>15 years). Most experts were employed in universities, research institutes, or other institutions (including the public sector, international organizations, NGOs, and the private sector); thus, two binary groups were created. The respondents were grouped among CA (five CA countries and Afghanistan) and international experts (all other countries) in terms of residence. The gender and language features were grouped into two (male-female and Russian-English) categories. Accordingly, the responses given by the participants on the relevance of the suggested water security dimensions (urban and household, economic, environmental, and hazards) to the CA context were also grouped into four main categories.

The clustering analysis was conducted to reveal behavioural patterns of respondents towards water security dimensions in CA by assessing similarities and dissimilarities among different socio-demographic features of the participants. For the implementation of the clustering, the initial Delphi survey ratings (1/low-10/high) given by the respondents on the significance of water security dimensions in CA and the national priorities were grouped into three categories: low (1–4), moderate (5–7), and high (8–10) significance. Annex B presents the initial values of variables and their categorization into the groups mentioned above. We estimated how much the answers of two individual participants varied within the groups mentioned above by computing the Euclidean distance across all of their responses. In particular, we calculated the squared difference of each answer, summed it across all questions, and then computed the square root. The resulting measures are the distances between the two questionnaires. The same procedure was repeated for all binary pairs of participants, thus resulting in a so-called distance matrix. Distance matrices are square and symmetric matrices consisting of all possible pairwise distances, where the rows and columns represent the respondents. This analysis was performed for both Delphi rounds, resulting in two distance matrices. To quantify the variability of answers for a predefined group (e.g., the group of participants whose age lies between 18 and 34), all pairwise distances of the participants that fall into this category were averaged. This has enabled us to quantify the variability within the groups in both Delphi rounds.

We further conducted a distance-quantification analysis of the groups by computing the average answer for each question across all participants. The combination of all average answers across all participants is termed the grand average (the dimensionality of this vector is the number of questions). Next, the Euclidean distance was calculated between the participants' given answers to the grand average. As a result, we obtained one distance measure per participant (i.e., how different are this participant's answers to the grand average?). Further, the participant's socio-demographic data was employed to calculate the distances of the groups to the grand average. If, for example, a given participant belongs to the 18–34 age group, her subject-specific answer distance will appear in the calculation of this specific group. Going through each participant and group, it is possible to calculate the average distance of each group to the grand average. This measure gives an idea of how much a given socio-demographic parameter (e.g., age, education) affects the opinion in terms of the diversion of the mean.

We also applied inferential statistics to detect whether any socio-demographic features may be associated with the respondents' views on water security in CA. A multinomial logistic regression (MNL) was introduced to identify the potential effects of the respondents' background on each CA country's water security dimensions and national priorities. The MNL regression models were conducted separately for each water security dimension and the potential priorities for each CA country and Afghanistan with five predictor variables (education, experience, employment, age, and residence). The reference category of the dependent variable in all models was represented by the low relevance rating for water security dimensions and national priorities. The MNL findings are presented only for the statistically significant outputs on model fitting, pseudo-R-Square, and parameter estimates.

TABLE 1 Summary of respondents' background.

Survey Period		September- October 2020
Number of invited professionals		417
Participants initiating survey		160
Participants completed survey		115
Socio-demographic features		
Gender	Male	63%
	Female	37%
Age	18–34	22%
	35–54	52%
	54 and older	27%
Education	Up to bachelor's degree	41%
	Postgraduate degree	59%
Employment	University/Research institute	63%
	Other[a]	37%
Experience	1–5 years	27%
	6–15 years	37%
	More than 15 years	36%
Language	Russian	40%
	English	60%
Citizenship	Regional[a]	66%
	International	34%
Residence	Regional	53%
	International	47%

[a]Note: Other = government agency, international organization, NGO, corporate firm, consultancy firm, self-employed; Regional = Central Asia and Afghanistan, Source: adapted from Assubayeva (2021).

Results

Profile of Delphi participants

A total of 417 invitations were sent to regional and international professionals for participation in the two survey rounds. As presented in Table 1, about 1/3 of the initial invitees participated in the two survey rounds. The number of complete responses relevant to the survey participants remained the same (73%) in both rounds. About two-thirds of the participants were represented by the male gender, whereas about half of the respondents were 35–54 years old in both rounds. Interestingly, more than half of the respondents acquired postgraduate degrees, similar to the number of participants employed in tertiary education institutes. An almost equal distribution of respondents is noticed in terms of the years of experience in the water sector. The Russian-speaking participants represented a considerable amount (40%) of the respondents. Overall, a representation of professionals from 24 countries was noted in the two rounds. However, about 2/3 of the respondents came from CA countries and Afghanistan, whereas other countries with considerable representation were from Germany, Switzerland, the Netherlands, the United States, and China, in descending order. Also, some of the participants of CA origin were residing abroad, as mentioned in the contributors' residence profile.

Water security priorities and agreement rates

As presented in Table 2, more than half (59%) of the participants noted that economic activities (e.g., irrigation, hydropower) are the most vital water security dimension in CA, followed by the urban and household facilities (e.g., sanitation, drinking water), natural hazards (e.g., floods, droughts), and environmental aspects (e.g., river and lake ecosystems). In the second survey round, the agreement rate increased by over 20% and became distinctively higher (79%) for the ranking order of the relevant dimensions.

The agreement rate on the most critical aspects (attributes) affecting each water security dimension in CA ranged from 59% to 75% in the first round. A remarkable increase (28%) was noticed in the second round for the construction and management of irrigation systems related to the economic dimension, which reached almost a consensus (94%). In the second round, an equally high increase in the agreement rate (25%) appeared for the construction and

TABLE 2 Summary of agreement/disagreement rates.

Survey rounds	1st Round	2n round	Agreement Diff
Water security dimensions and priorities	**Agreement (%)**	**Agreement (%)**	**2nd -1st round (%)**
Water security dimensions			
1st Economic activities	59	79	20
2nd Urban and Household facilities			
3rd Natural Hazards			
4th Environmental aspects			
Water security attributes			
Economic dimension: construction and management of irrigation systems	66	94	28
Urban & Household dimension: construction and management of drinking water supply facilities	59	84	25
Hazards dimension: management and protection from droughts	68	67	−1
Environmental dimension: management and conservation of rivers and river basins	75	84	9
Water security trends			
The Economic aspects are also gaining importance in the last 10 years, however, at a slower pace than the Environmental-related aspects	64	63	−1
The Urban & Household aspects in CA were significant in the policy agenda until 10 years ago but now are in decline	47	43	−4
The water-related Hazards have gained more attention on the policy level in the last 10 years	65	67	2
The Environmental aspects of CA have been widely discussed in the last 10 years	64	72	8
Water security priorities			
AF: Improvement of drinking water use in rural and urban areas	44	65	21
KZ: Improvement of river basin management	50	73	23
KG: Improvement of hazard plans for landslides	27	49	22
TJ: Improvement of irrigation management for agriculture	38	60	25
TM: Improvement of drinking water use in rural and urban areas	46	47	1
UZ: Improvement of irrigation management for agriculture	53	84	31
Effectiveness of institutions			
There are significant concerns about the effectiveness of the current institutions and mechanisms dealing with water security issues in CA	64.7	84.1	19.4

Note: AF, Afghanistan; KZ, Kazakhstan; KG, Kkyrgyzstan; TJ, Tajikistan; TM, Turkmenistan; UZ, Uzbekistan; Agreement Diff. = The agreement rate achieved in the second round minus the agreement rate of the first round. Source: adapted from Xenarios et al. (2020), Assubayeva (2021).

management of drinking water supply facilities related to the urban and household dimensions. However, the increase for the management and conservation of rivers and river basins in the environmental dimension was mild (9%), while in the case of management and protection from droughts in the natural hazards dimension, there was a slight decrease (−1%). It is worth mentioning that a third of the respondents argued that droughts were not the central aspect of the hazards' dimension.

When the participants were asked to comment on the water security trends reflected in the literature review and their implication on a policy level, a considerable agreement rate was obtained across all dimensions except for the urban and household dimension. For the latter, less than half of the respondents (47%) agreed that the urban and household dimension was on the policy agenda until 10 years ago and currently is in decline. An even lower agreement rate (43%) resulted during the next round. For the case of the other dimensions, nearly two-thirds agreed in the first round that the economic dimension had gained importance during the last 10 years, the water-related hazards have gained more attention on the policy level in the past 10 years, and the environmental aspects are widely discussed in CA the last decade. Remarkably, the second Delphi round did not achieve any higher agreement on water security trends—some decline even, except for the case of the environmental dimension.

Regarding water security dimensions and attributes for each CA country, participants were requested to select the most significant ones per their own experience. In the first round, irrigation management was highly prioritized for Uzbekistan by more than half of the participants (53%) and, to a lesser extent, the need for improved river basin management in Kazakhstan (50%), drinking water in Turkmenistan (46%) and also in Afghanistan (44%). There was a lower but distinctive

prioritization for irrigation management in Tajikistan (35%) and water-related hazards in Kyrgyzstan (27%).

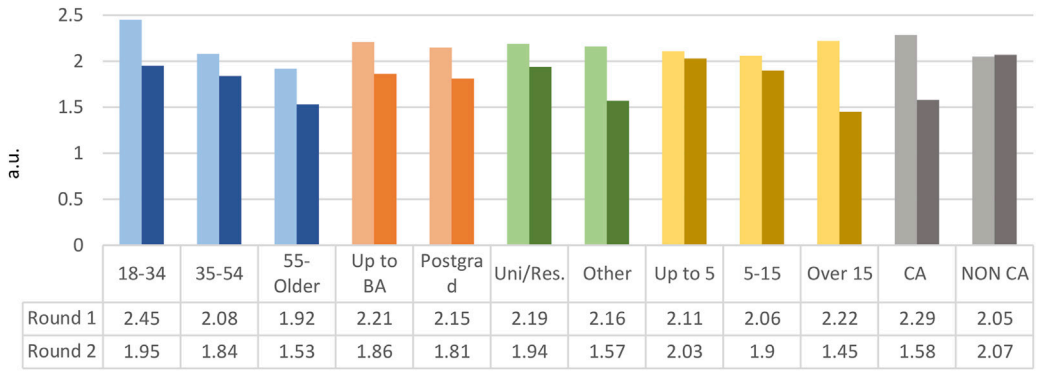
The agreement rate of all the national prioritizations increased in the second round ranging from 21% to 31%, except for Turkmenistan, where the rate remained almost the same. The participants expressed significant concerns about the effectiveness of the current institutions and mechanisms for water security issues in CA in the first round (64%), which increased substantially in the second round (84%).

A preliminary description of the Delphi findings has been presented in Assubayeva (2021), mainly focusing on the theoretical background of similar approaches.

Clustering analysis

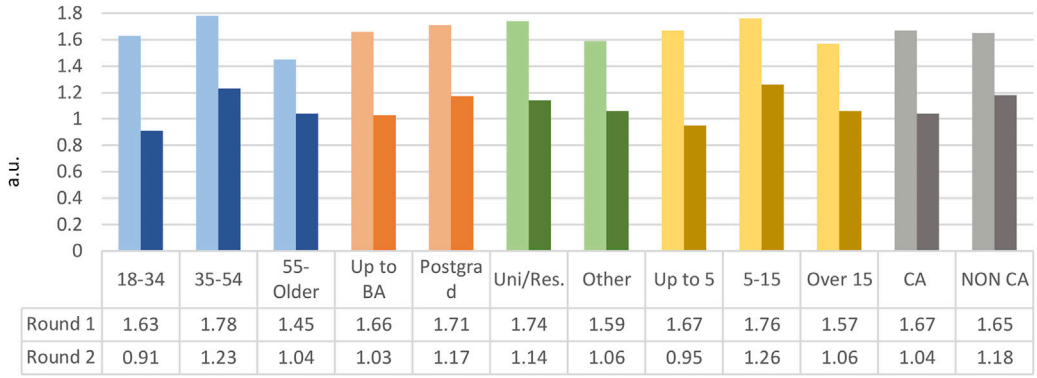
The clustering analysis identified whether a higher agreement rate (lower variability) had been attained within each group in the two survey rounds. It is noted that the agreement rate may not imply consent or discordance on different questions but rather homogeneity and better coherence within the groups. Also, the variability numbers represent relative values comparable between all the groups. As presented in Figure 2, individual groups' responses have lower variability in the second round, which indicates that a higher agreement rate has been attained from the first to the second round. The coherence is more distinguished in the case of the younger generation (18–34), the respondents non-employed in university/research centres, experienced professionals (>15 years), and the respondents residing in CA.

The mean distance of each group from the 'average' response is shown in Figure 3. The 'average' response represents the mean answers calculated across all posed questions for the two survey rounds. The distances are comparable between groups as well as rounds. The highest divergence from the 'average' response occurs for the age group of 35–54, the postgraduate holders, and the respondents employed in universities/research institutes. A remarkable alignment with the 'average' response is presented across all groups in the second survey round, with slight fluctuations between the groups.



	18-34	35-54	55-Older	Up to BA	Postgrad	Uni/Res.	Other	Up to 5	5-15	Over 15	CA	NON CA
Round 1	2.45	2.08	1.92	2.21	2.15	2.19	2.16	2.11	2.06	2.22	2.29	2.05
Round 2	1.95	1.84	1.53	1.86	1.81	1.94	1.57	2.03	1.9	1.45	1.58	2.07

FIGURE 2
Agreement rate and variability within each group in the two Delphi rounds, Note:a.u = arbitrary units.



	18-34	35-54	55-Older	Up to BA	Postgrad	Uni/Res.	Other	Up to 5	5-15	Over 15	CA	NON CA
Round 1	1.63	1.78	1.45	1.66	1.71	1.74	1.59	1.67	1.76	1.57	1.67	1.65
Round 2	0.91	1.23	1.04	1.03	1.17	1.14	1.06	0.95	1.26	1.06	1.04	1.18

FIGURE 3
Distance of the groups from the 'average' response in the two Delphi rounds, Note:a.u = arbitrary units.

TABLE 3 Potential effects of respondents' profile on water security dimensions in CA.

Urban and household dimension of water security

Model Fitting Information (Likelihood Ratio Tests)							
Model	Chi-Square	df	Sig	Pseudo R-Square			
Final	14.742	8	0.064	Cox and Snell: 0.148			
Parameter Estimates							
UH[1]		B	Std. Error	Wald	df	Sig	Exp(B)
Moderate	Experience[2] = 1–5 years	2.181	1.195	3.328	1	0.068	8.854
High	Experience[2] = 6–15 years	1.292	0.649	3.966	1	0.046	3.640

1. The reference category is low relevance to urban and household dimension
2. The reference category is the experience of more than 15 years

Economic dimension of water security

Model Fitting Information (Likelihood Ratio Tests)							
Model	Chi-Square	df	Sig	Pseudo R-Square			
Final	16.502	8	0.036	Cox and Snell = 0.145			
Parameter Estimates							
ECON[1]		B	Std. Error	Wald	df	Sig	Exp(B)
Moderate	Employment[2] = University/ Research Institute	-1.928	0.883	4.761	1	0.029	0.145
High	Intercept	1.797	0.836	4.617	1	0.032	

1. The reference category is of low relevance to the economic dimension

2. The reference category is employment in other sectors

The differences between rounds in Figure 3 were statistically significant for all considered sub-groups ($p < 0.05$) when performing a Mann–Whitney nonparametric test. All statistical analyses were Bonferroni corrected for multiple comparisons.

Multinomial logistic regression regression results

The regression iterations of the MNL model identified some potential associations for the urban and household dimensions with three predictors (education, experience, and employment). The reference category is the low importance of the urban and household dimension in the context of CA, while the statistical significance threshold is 10% ($p < 0.1$). As shown in Table 3, there is a probability that respondents with low (<5 years) and moderate experience (6–15 years) will give a higher emphasis on the urban and household dimension in relation to more experienced (>15 years) ones. Similarly, the MNL model identified a better fit for the economic dimension with three predictors (education, experience, and employment). The respondents with higher professional education (postgraduate degree) and significant experience (>15 years) employed in other

TABLE 4 Potential effects of respondents' profile on national water security priorities.

National Priorities	Age	Education	Experience	Employment	Residence
Development of hydropower for electricity and agriculture in Afghanistan					CA and Afghanistan
Improvement of drinking water in rural and urban areas in Kazakhstan	18–34		1–5 years		
Improvement of drinking water in rural and urban areas in Kyrgyzstan					CA and Afghanistan
Improvement of irrigation management in Tajikistan	18–34	Up to BA degree		Un./Res.Inst	
	35–54				
Improvement of irrigation management in Uzbekistan	18–34	Up to BA degree			

Note: Un./Res.Inst. = University/Research Institutes, Source: Asssubayeva (2022).

sectors than university/research institutes are likely to give high priority to the economic dimension in CA. A moderate significance is evident for the respondents employed in university/research institutes. The likelihood ratio tests revealed that the models with the environment's and the hazards' dimensions show statistically insignificant and poor results; thus, the regression results are not presented.

For the case of the potential effects on the national priorities suggested for CA countries, we summarized all the MNL results in Table 4 by indicating the statistically significant predictors ($p < 0.1$). It is also noted that all the national priorities were initially presented to the Delphi participants before identifying the most preferred ones for each CA country. As shown in Table 4, younger respondents (18–34) with educational backgrounds up to graduate level seem to favour irrigation improvement in Uzbekistan and Tajikistan. The respondents residing in CA support drinking water interventions in Kyrgyzstan, while young and relatively inexperienced participants also favour drinking water interventions in Kazakhstan. The CA residents also seem to encourage the development of hydropower stations for multiple uses in Afghanistan.

Discussion

The current study attempted to decipher the water security concept in CA as perceived by water professionals with experience and expertise in the region by also assessing the potential differences from the bibliometric review findings. The Delphi method was introduced to identify whether water professionals could agree on the dimensions and priorities that may affect water security in CA and each country. The desirable consensus rate in the Delphi method varies within the literature; however, a range above 70% is mainly approved as a satisfactory agreement rate (Birko et al., 2015). The high consent of respondents (79%) on the selected security dimensions and the higher agreement rate gained among the two rounds (+20%) suggest that Delphi could have mobilized water professionals towards a more commonly accepted notion of water security in CA.

The prioritization of the economic dimension coincides with the initiatives of upstream CA countries to construct more hydropower stations for economic development and for downstream CA countries to rehabilitate irrigation systems to improve rural livelihoods and increase agricultural production (Abdullaev et al., 2019). The infrastructural context of the economic dimension is also asserted in this study, evident from the very high agreement on the construction and management of irrigation systems as the most significant attribute (94%). The urgency to vastly support with about US 8.7 billion the rehabilitation of the ageing water infrastructure in CA, was recently highlighted by development agencies (Vinokurov et al., 2021). The pronounced agreement rate (84%) on the urban and household dimensions could also be driven by similar infrastructural and engineering reconstruction demands on the water supply systems, as mentioned in a recent report developed by the UN-Water organization (2021). The comparatively lower agreement rate on drought occurrences (67%) in the hazard dimensions came unexpectedly as some parts of the CA region faced severe droughts and heatwaves in 2020–2021, causing water shortages for agriculture. Moreover, the recent IPCC report (2021) highlighted that climate change aggravates the higher frequency and intensity of weather extremes in CA by causing insurmountable damages to livelihoods and the natural environment.

The river basin management and conservation are highly prioritized in the environmental dimension at a near consensus rate (84%). The high agreement rate could probably be explained by the effort of CA countries to introduce a hydrographic (river basin) approach as an operational tool for freshwater management (Yakubov, 2022). The river basin management reforms are heavily supported by different development and donor organizations, with varying degrees of implementation among the CA countries. There is also an effort to borrow elements from established basin approaches elsewhere, mainly from the European Framework Directive (WFD, 2000/60/EC) (Mukhtarov and Gerlak, 2013). The WFD has become the guide for the development of the European Union Water Initiative (EUWI), introduced in 2016 to countries of Eastern Europe, the Caucasus and CA (EU Water Initiative, 2022). The EUWI

supported National Policy Dialogues in CA countries to promote cross-sectoral and intergovernmental communication and coordination on policies regarding river basin management. Still, a fragmented and sectoral approach to water resources management prevails in CA countries, whereas the environmental dimensions are overlooked.

The respondents partly accept the water security trends reflected in the bibliometric review (Xenarios et al., 2020), while the anticipated consensus between the two rounds seems almost negligible. The different stance of water professionals could probably be explained by their practical experience on applied projects in CA, which possibly differ from the literature readings. Much of the funding from development agencies, with which many respondents are engaged, is still directed to infrastructural projects on irrigation and urban water systems. Many of these projects refer to climate change and its environmental implications; however, the primary goal remains to rehabilitate and develop infrastructural assets (Djumaboev et al., 2019; Vinokurov et al., 2021). On the other hand, the relevant literature mainly points to the environmental and global climate changes that will heavily affect infrastructure, society, and water governance and thus are more discussed among scholars.

Water professionals set different water security priorities for CA countries, reflecting conflicting national water interests and the lack of regional vision in transboundary water security. The consensus among national priorities for CA countries seems to be more distinguished for Uzbekistan, while the agreement rate was also nearly doubled for the case of Tajikistan in the second round. The finding for Uzbekistan could be justified by the still highest water consumption among CA countries, with an annual freshwater withdrawal of 58.9 billion cubic meters and the most extensive irrigation network inherited from the Soviet period (World Bank, 2022). This finding also aligns with a recent World Bank report suggesting targeted modernization of irrigation systems in Uzbekistan (World Bank, 2020). Similar irrigation expectations exist, especially in northern Tajikistan, where a part of the Ferghana valley is shared with Uzbekistan and Kyrgyzstan. During the Soviet era and to this day, the Ferghana valley remains the breadbasket of CA with heavily irrigated agriculture and large water pumping systems (Wegerich et al., 2012; Xenarios et al., 2019b).

The unexpected findings come from the prioritization of river basin management for Kazakhstan. The basin management approach has been established in the last 20 years but with limited funding and weak organizational support from the state. It is probably the respondents' views that Kazakhstan needs to monitor better transboundary river systems as about half of the freshwater sources originate from rivers outside the country. Drinking water is a significant challenge for rural and urban settlements in Afghanistan, which could justify the prioritization for the country and the higher agreement rate in the second round (Hayat and Baba, 2017; UN Water, 2021). Significant challenges are also evident in Turkmenistan's rural regions regarding water accessibility and quality, which could probably explain the voting for this attribute and the nearly doubling agreement rate in the second survey round.

The water professionals' community has repeatedly disputed the effectiveness of the current institutions and mechanisms to deal with water security in CA, which is also vividly presented in the findings. The Interstate Commission for Water Coordination in CA and the International Fund for Saving the Aral Sea (ICWC, 2022; IFAS, 2022) are the most significant regional organizations mainly focusing on freshwater management in the Aral basin. In both cases, however, the organizations are underfunded, with low skilled capacity, limited data availability, and international exposure, questioning their capability to deal with transboundary water security challenges (Krasznai, 2019; Sehring, 2020). Poor transboundary water governance in CA, including weak institutions coordinating transboundary water security issues, might escalate water resources challenges under growing demand and climate change impacts.

The avoidance of stating the respondent's expertise in the Delphi rounds may have created some bias towards the overrepresentation or underrepresentation of some professional backgrounds. It is, for instance, quite frequent that professionals with civil and hydraulic engineering backgrounds are engaged in water-related projects in CA. On the other hand, professionals with environmental and social backgrounds are often underrepresented. It is a possibility that the misrepresentation of professionals with different expertise could affect the study's findings. We, however, avoided enquiring about the particular expertise of each respondent in the Delphi rounds, as there have been many instances in CA where consultants and project managers are requested to have an interdisciplinary background with experience in various water-related projects. The inquiry about the particular expertise could overshadow the professional breadth of some respondents, and thus instead, we asked for the educational level and professional experience in the CA region.

The use of the Delphi method to elicit views on conceptual or technical aspects from specific target groups has been accused of subjectivity over the years by different scholars. It was indicatively mentioned that uncertain respondents could change their opinion from the initial survey round when a high agreement rate is noticed in the following rounds (Avella, 2016). Even though the Delphi studies focus on reaching consensus among panel members, identifying dissensus also matters and is often ignored (Birko et al., 2015). We acknowledge the inherent biases, and we tried to minimize the subjectivity factor by assuring total anonymity of respondents without exerting pressure in terms of responding time to the surveys. We also attempted to avoid potential bias from specific professional backgrounds, country of origin,

experience, educational status, and age by inviting participants that fulfilled all the relevant selection criteria as much as possible. We invited a wide range of experts on water issues; however, water professionals employed at universities and research centres expressed a higher willingness to participate in the study. We also tried to minimize the language barriers prevalent in the post-Soviet space by designing the two surveys in English and Russian. Using two survey rounds could have affected the agreement rate compared to running additional survey rounds (De Loe et al., 2016; Belton et al., 2019; Chan, 2022). However, we communicated with some of the respondents between the first and second rounds and realized that additional rounds would possibly lead to low turnover, thereby biasing the results as fewer participants would evaluate the surveys' findings.

The clustering analysis offered insight into the behavioural aspects of the respondents' profiles per different socio-demographic features. The improved homogeneity in the second survey round, as shown in Figure 2, justifies our intention for the respondents' segmentation into fewer groups by presenting an overall lower variability or higher agreement rate within each group. Also, the higher coherence among experienced water professionals (>15 years) from the CA region could come from the homogeneous perception of respondents who were educated during Soviet times. In the Soviet era, the water management paradigm was mainly related to constructing hydraulic infrastructure, advancing irrigation and hydropower in the CA region and ultimately improving economic welfare. A similar trend from experienced respondents is reflected in the MNL findings, showing the preference for the economic dimension. In contrast, the homogeneity among the younger generation (18–34) might indicate different water management paradigms, particularly the Integrated Water Resources Management (IWMR) approach that international donor organizations widely promoted over the last 2 decades (Sehring et al., 2019).

The distance from the 'average' response in Figure 3 indicates that all groups assert a higher coherence in the second survey round. The higher divergence from the 'average' response among respondents aged 35–54 compared to the other age groups could be driven by varying views between CA and international water professionals. The most significant number of CA water professionals aged 35–54 have faced severe downsizing of water organizations after Soviet times due to financial deficits (Krasznai, 2019). Their water security perception is oriented towards the day-to-day sustenance of drinking, irrigation and hydropower systems, primarily through repairing works. On the other hand, the views of professionals outside CA are related to longer-term planning and interdisciplinary approaches where technical interventions, institutional reforms, and environmental restoration could respond to the water security needs in the region. We did not explore the interactions between the groups (e.g., respondents 18–34 with a postgraduate degree) in the clustering analysis as this would require a more extensive assessment. The MNL regressions attempted to infer associations of the defined groups with the water security dimensions and priorities. It is uncertain that the MNL results may lay some foundation on the respondents' background regarding particular perceptions of security aspects. However, the findings could trigger a more in-depth assessment of the role of the respondents' profile on Delphi's approaches to water security and other similar methods.

We more broadly anticipate that the proposed methodological approach can enable researchers to obtain an in-depth understanding of the behavioural responses of Delphi participants. The clustering approach can assess the agreement rate within and between the predefined groups of participants and estimate the group diversion from the average response. The MNL regressions can additionally explore the profile of the predefined groups and enhance the validity of the clustering approach.

Conclusion

Water security is considered a context-specific and multidimensional concept with significant implications for fair allocation among water users (Gerlak et al., 2018). The transboundary freshwater systems add another layer of complexity to water security by considering different perceptions of upstream and downstream regions, developed and less developed countries, hydropower, and irrigation-dependent ones, as occurs in the case of CA (Varady et al., 2020). Although some studies refer to different dimensions of water security in CA and the individual countries, there is still a vacuum in the perceptions of water professionals engaged in water security projects and initiatives in the region. The current study attempted to shed some light on the views of different water professionals from diverse backgrounds about water security priorities in CA and each country through the Delphi approach enriched with clustering and statistical analyses. We further explored the potential discrepancies between the literature findings and the professionals' views on prioritizing different water security dimensions in CA.

The findings indicate that although CA has been deeply affected by the Aral Sea desiccation's environmental disaster, the economic rather than the environmental dimension is the ultimate priority for nearly all water professionals. It is likely that if the survey had focused on the Aral desiccation and the repercussions to water security, the outcomes would have probably ascended the environmental dimension as a significant determinant. We, however, tried to refrain from the Aral Sea disaster, as it has been extensively discussed among water professionals. Also, the most significant repercussions are found in Kazakhstan, Uzbekistan, and, to a lesser extent, in other countries.

This study reveals the prioritization of the economic dimension by water professionals, which differs from the findings of the academic discourse on water security in CA (Xenarios et al., 2020). Furthermore, it indicates different

viewpoints on developing a regional security approach in CA. The regional approach should also consider the different prioritizations suggested for each CA country by the water professionals and the current initiatives taken on a national level. There are, for instance, only a few initiatives in Kazakhstan related to river basin management, while in Turkmenistan, gravity is given to cotton irrigation rather than drinking water. The irrigation priority in Uzbekistan and Tajikistan mentioned in our findings coincides with the policy-making agenda and planning of the two countries for the following years (ICWC, 2022). However, the river management initiatives are taken on a country level but without a broader transboundary context. More research should be conducted on the drivers and pressures in the freshwater systems in CA through a transboundary approach by attempting to initiate local activities between neighbouring borderline communities to avoid potential future conflicts.

The inheritance of massive water supply infrastructure commonly shared between CA countries from Soviet times, the different demands between upstream and downstream, and the various development paces within the region bring significant challenges to establishing an integrated water security concept. However, we believe that the Delphi method's enrichment with the clustering and the regression analysis could offer some reliability to the water security priorities suggested by water professionals. Moreover, by signifying the preference dynamics among the participants, the two Delphi rounds led to a better understanding of the subgroups' behavioural aspects. Comparing the study findings with the bibliometric review has shed light on the different standpoints of water security notions in CA by indicating the need for common interpretations from the research and professional community. Future research should also explore the perspective of local communities and include their views in the water security debate in CA.

In addition to approaching water security challenges and cooperation in CA, our methodology could be transferred to other domains within environmental science and beyond. We, therefore, believe that the suggested approach could contribute to the general ideas of how digital humanities can be pursued in the future by improving communication among professionals on significant socio-ecological challenges.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by IREC GSPP Comittee of Nazarbayev University. The participants provided their written informed consent to participate in this study.

Author contributions

AA: Writing original draft, Data Collection and Analysis on Delphi and Multinominal Logistic Regression; SX: Conceptualization, Writing original draft, Supervision of overall data collection and analysis, project administration; AL: Writing original draft, Data analysis of Clustering Method; SF: Conceptualization, Supervising original Draft, Supervision Clustering Analysis.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fenvs.2022.970633/full#supplementary-material

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