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To cite this article: Stefanos Xenarios *et al* 2021 *Environ. Res. Lett.* **16** 013001

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OPEN ACCESS

RECEIVED
4 May 2020

REVISED
20 August 2020

ACCEPTED FOR PUBLICATION
3 November 2020

PUBLISHED
18 December 2020

TOPICAL REVIEW

A bibliometric review of the water security concept in Central Asia

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Keywords: transboundary basins, water resources management, governance, environment, engineering, Central Asia

Abstract

Engineering, economic, social sciences, geophysical, and integrated modeling studies have approached the assessment of water security in Central Asia (CA) in distinct ways. Different indicators and indexes have been introduced to assess the most vulnerable aspects of water use in this region. Until now, though, the suggested approaches are often represented in a fragmented manner, while the relevant indicators cannot fully attribute the vulnerability status of a country or on a regional level. This can result in diverging perceptions of the water security situation in policy dialogues, also affecting bilateral and multilateral relations among the countries in CA. In this study, we conduct a bibliometric review on the approaches and methods that directly or indirectly touch upon the water security perceptions in CA. We employ data mining techniques to explore trends in the conceptualization of water security in the region since the breakup of the Soviet Union by also identifying the water interests and priorities set by each country. The findings reveal that within the last decade, the water security-related studies have given much importance to technical and infrastructural means to protect human livelihoods against global environmental changes but also to foster economic growth. The water governance and management aspects are largely overlooked in favour of more techno-centric approaches. These findings are expected to clarify further the perception of the water security concept within CA by indicating the geophysical, institutional, and historical challenges that need to be met for a mutual understanding among the countries in the region.

1. Introduction

Over the past two decades, the term water security has been increasingly used in scholarship and policy debates. It reflects growing concerns about human and earth system vulnerability when faced with water-related challenges, while attention is mostly given to national and regional water needs (Cook and Bakker 2012, Bakker 2012, Gerlak and Mukhtarov 2015).

There are many definitions of water security, and the following one of UN Water (2007) captures the relevant aspects also found in other sources: 'The capacity of a population to safeguard sustainable access to adequate quantities of and 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 stability'.

In natural sciences, water security is often narrowly focused on the functioning of the biosphere, while other scholars stress a broader approach through cross-disciplinary perspectives to better understand and address water challenges (Bakker 2012). The definitions and discourses of water security vary by the importance given to different aspects, like the urban and rural context, economic development, governance as well as prioritizations set by the relevant authors (Ginkel *et al* 2018, Hoekstra *et al* 2018, Jensen and Wu 2018).

Economic development is also an influential factor in the interpretation of water security and the perception of urgency in dealing with water-related threats. Indicatively, in the Global South, development concerns prevail, and water security is foremost understood by its nature for achieving high economic growth and poverty reduction (Grey and Sadoff 2007, Gerlak and Wilder 2012). Also, the sociopolitical processes and historical contexts may vary between regions by prioritizing different objectives on the water security notion (Saravanan *et al* 2009).

Consequently, different policy actors and academics from different disciplines use the water security concept in diverging ways, and often also with a limited explanation on the contextual background and the adoption of the relevant terminology (Allouche *et al* 2011, Strickert *et al* 2016). It therefore often remains unclear which exact risks the security term reflects and to what extent the respective policy recommendations match. The blurred definition of water security has raised strong political repercussions in national but also international context, especially in areas where transboundary water systems are prevalent (Burgess *et al* 2013).

In order to get a better understanding of at least the academic realm, on how scholars use the water security concepts and which are the relevant challenges in a given region, we undertake a bibliometric review of academic papers on water security in Central Asia (CA). The region of CA represents a good example of a region facing water security challenges, with complex transboundary water systems, where the countries are water-dependent to each other not only due to geophysical conditions but also because of the Soviet past where interconnected infrastructural assets were constructed (Djumaboev *et al* 2019).

Most parts of the CA region belong to the Aral Sea basin with two major rivers—Syr Darya and Amu Darya—flowing through six countries, namely, Afghanistan, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan. In the arid climate of the basin, water is a key driver for food security, energy security, biodiversity, and economic development for more than 50 million people. Over 8.4 million hectares of irrigated agriculture contribute to approximately 20% of regional GDP, with an employment of 40% of the population (Xenarios *et al* 2019a). Over 45 large hydropower stations in the region generate 37 GWh yr^{-1} of hydropower, accounting for 27% of average energy consumption in the Aral Sea basin and about 90% in Kyrgyzstan and Tajikistan. Figure 1 presents an overview of the Aral Sea basin by depicting the major geophysical features and the ongoing hydropower constructions.

The rivers provide several environmental goods and services, and the degradation has led to severe environmental and economic impacts, including the drying-up of the Aral Sea, polluted water and land, and desertification. In Soviet times, water and energy resources were part of the region's inter-republican integrated management system. Water from the Amu Darya and Syr Darya rivers was stored in upstream reservoirs in the Kyrgyz and Tajik Social Soviet Republics (SSRs) and supplied extensive irrigation systems in the downstream Kazakh, Turkmen and Uzbek SSRs for agricultural production. In exchange, oil, coal, and gas were transferred from downstream to upstream republics in winter for their energy needs. The intra-regional transfer ensured that no hydropower energy would be produced upstream in the winter season to avoid flooding incidents downstream, while uninterrupted water flow would be ensured in summer for irrigation in downstream countries (Xenarios *et al* 2019b). This system has almost disintegrated in 1991 after the collapse of the Soviet Union and paved the way for the prioritization of the use of natural resources, including water systems, according to the national needs of each CA country.

Lacking energy supplies, the upstream countries faced a worsening energy crisis in the 1990s. The energy crisis drove upstream countries to switch the reservoirs for hydropower use by reducing water discharges in summer and increase outflow during the winter season. This led to reduced water availability for irrigation in the summer of downstream countries and threatened their food production and security. As a consequence, disagreements and tensions among states about seasonal water allocation increased and got reinforced by projects to build new dams, mostly in upstream countries.

There is a widespread perception (and also political instrumentalization) that the energy security of upstream countries can only be achieved at the cost of downstream agricultural water and food security (Xenarios *et al* 2018a). Since tensions among upstream and downstream CA countries are largely grounded in the conflict between water use for agriculture (downstream) and energy production (upstream), the water-energy nexus and the attempts for a coordinated governance approach are often in focus (Xenarios *et al* 2018b).

The water-related challenges in the region are amplified by the impacts of population growth, environmental degradation, economic development, competing for water uses, and climate change. Increased variability and changes in the flow pattern could have dramatically adverse social, economic, and environmental consequences across CA. Water sharing for different uses within and moreover between the countries represents an issue of increasing importance to peace and prosperity in the region. Although different water-relevant institutions have been formed among CA states, tensions over the sharing of water exist, which leads many to fear the possibility of political instability (Zakhirova 2013, Wegerich *et al* 2015).

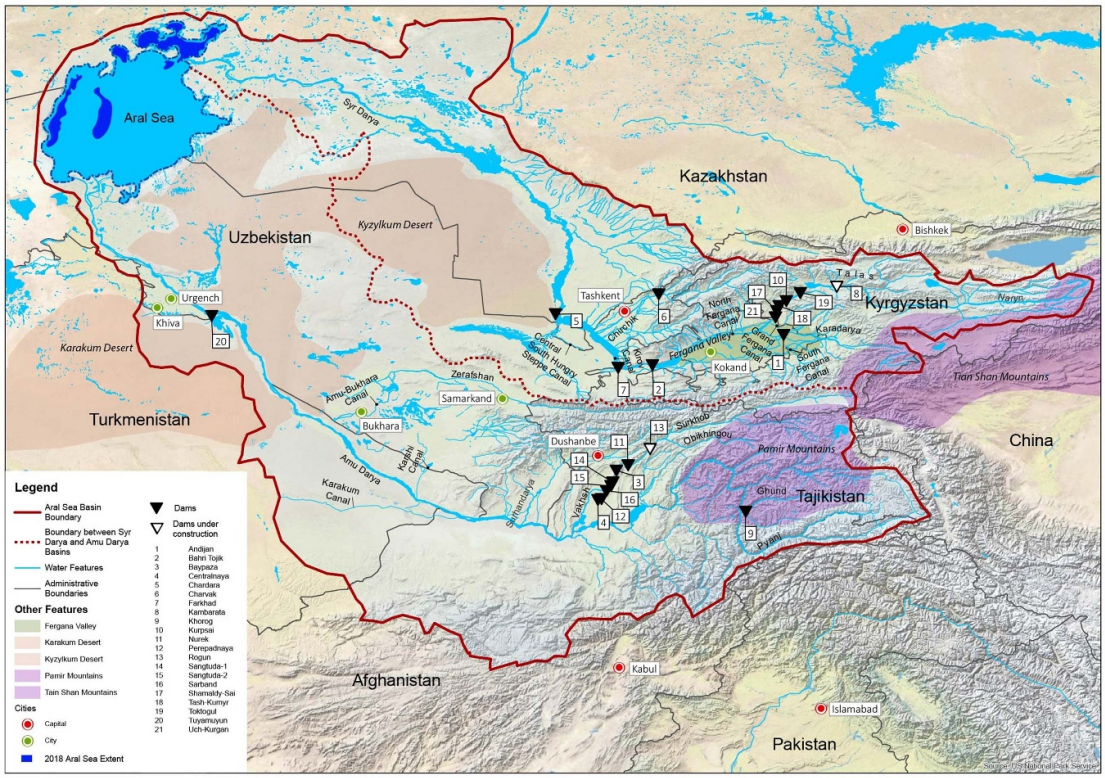

Figure 1. Overview of the Aral Sea basin and the hydropower developments in the Central Asia region. Source: Hamid Mehmood in Xenarios *et al* (2019b).

The current study aims to identify how water security is perceived by literature in CA on regional and country-wise context. We conduct an extensive bibliometric review to assess the most relevant studies associated with water security in CA according to a set of criteria and indicators structured in a multi-layered approach. The data sources are drawn through an in-depth review of the literature published after 1991(i.e. the independence of the countries from the Soviet Union). The identification of the most prominent aspects of water security perspectives in CA is conducted through quantitative and qualitative analysis and data mining techniques. Further, a timeline analysis presents the changes in the importance of different water security aspects as defined and analysed in the relevant literature. Also, the significance attributed to each CA country with regard to the security of water sources is explored while we attempt to identify the background of the research institutes leading water security studies in the CA region.

2. Methodology

We initially trace all the relevant language literature on water security in CA after the independence period (1991) and until today. For the literature analysis, we borrow thematic categories and keywords from the Asian Water Development Outlook (AWDO 2013, 2016) framework. The Asian Development Bank developed the AWDO in an attempt to cover the different dimensions of water security and evaluate the performance of all Asian countries through a set of comprehensive indicators.

Two consecutive reports of the AWDO (2013, 2016) have adopted a Water Security Index which identifies national water security being achieved when the society 'can successfully manage their water resources and services to (a) satisfy household water and sanitation needs in all communities; (b) support productive economies in agriculture, industry, and energy; (c) develop vibrant, livable cities and towns; (d) restore healthy rivers and ecosystems; and (e) build resilient communities that can adapt to change' (AWDO 2016, p 15).

The two consecutive reports of AWDO have adopted five dimensions to assess water security in Asia as the household, economic activities, urban water management, environmental management and resilience to water-related disasters. The AWDO framework may be criticized for the partial overlap of the dimensions and absence of more representative indicators. Still, AWDO is one of the few comprehensive platforms that has repeatedly (2013, 2016) assessed the concept of water security in a quantitative manner for the entire Asian region. Both AWDO reports have provided solid documentation of the performance of all Asian countries along the five selected dimensions through statistical techniques and ranking assessments. We adopt two dimensions from AWDO reports, namely the economic

and environmental, by further revising the resilience dimension to hazards which is more applicable to the CA context. We merge the dimension of household and urban management due to the high overlap between the two categories. We also add the dimension of water governance to explore the relevance of the literature review with societal perspectives.

A Boolean search is introduced by primarily querying the phrase water security CA in Scopus and Web of Science Databases. Additionally, we cross-check the results and search for additional entries through ten databases that cover the majority of published studies worldwide on water security in CA (Academic Search Premier, OpenDissertations, Business Source Complete, Communication & Mass Media Complete, EconLit, GreenFILE, Library, Information Science & Technology Abstracts, MasterFILE Premier, SocINDEX with Full Text).

The second layer of literature review through Boolean research identifies the water security term matched in a country-specific context. All five countries of CA are considered as well as Afghanistan, which shares major transboundary basins with Tajikistan, Uzbekistan, and Turkmenistan. The findings are cross-checked with the first layer of literature research to avoid duplication.

In turn, more context-specific research is performed on the indicators (keywords) to be related to each security dimension, which represents the third layer of research in the literature review. The selection of indicators comes from three main sources, namely the AWDO framework, communication with experts on water management in CA, and word frequency assessment of the collected literature. For the case of experts' communication, we have asked the feedback of the suggested keywords from researchers along with the 16th Bi-Annual Conference of the European Society for CA Studies held in Exeter (UK) on 25th–30th June 2019. For the case of word frequency assessment, we identify the most representative keywords in the collected literature related to the security of water resources by also allowing synonyms or similar concepts to be traced. The word frequency approach allowed us not only to discover additional keywords but also to confirm whether the keywords suggested by the AWDO framework and the experts were also recurrently presented in the literature.

The search in all the above dimensions and layers was focused only on peer-reviewed English language journals from 1991 to 2019. We were initially searching also for other languages and mainly Russian, which was predominant until recently for CA-related studies. Throughout our literature research, we have noticed that quite a few Russian-speaking studies were primarily published in regional (CA) or Russian-based journals and have been later revised and improved to be published in English language ones with higher readability and accreditation. The inclusion of the previous Russian version would have essentially double-counted some of the studies, thus the English articles only were preferred.

Further, the reasoning behind the research filter on peer-reviewed journals only is the partial overlap that we have come across in working reports and books that appeared to be further distilled in journal studies by the same authors. The selection of 1991 as a baseline demarcates the evolution of water security studies after the post-Soviet era in the entire CA region. For better identification of the main components used in our analysis, we adopt the term 'Dimensions' whereas the keywords adopted in the third layer are acknowledged as 'Attributes'. The adoption of the above terms is based on a similar structure of the AWDO frameworks that were extensively used in the current study.

The selected dimensions, layers, and indicators are presented in table 1. A different colour font marks each Dimension and its Attributes, which is further followed in other tables and figures throughout the study. It is mentioned that although certain keywords were searched in the bibliometric review, in table 1, we identify the relevant indicators related to the particular keywords.

We further identify the amount of sources (studies) referring to the Dimensions by accounting the word frequency of the keywords mentioned in table 1. We exclude the keywords presented in the reference list of each study along the counting process as they do not have direct relevance with the content. We also thoroughly read each study to exclude the referred keywords that are not emphasizing the security of water resources in CA. The correspondence of each Attribute and Dimension is conducted though a data mining approach with qualitative-based software (NVivo 12) as well as Python-based programming and coding analysis. In turn, we conduct a cross-tabulation analysis to assess to what extent the collected studies may comprise the same input source for more than one Dimension.

Also, two chord diagrams are developed to show the relationship of each CA country, including Afghanistan, with particular Attributes and Dimensions. A chord diagram (or radial network diagram) is a graphical tool, which allows examining feature relationships in data. A circle is divided into arcs, where arc lengths represent the importance of a specific feature. In our case, an arc can represent either a country of CA or an Attribute. The connection strengths of the CA countries with the Dimensions and Attributes are calculated through the weighted average of the relative word occurrence across all studies.

We also explore the dynamics of the relevant literature across the examined period from 1991 till 2019. We further compare the study findings with the global literature trends and the overall increase in peer-reviewed publications. A number of attempts to quantify the growth rate of all scientific papers have been made, and the estimates vary substantially.

Table 1. Dimensions and Attributes of water security in CA.

First Layer
Water Security Central Asia
Second Layer
Kazakhstan—Uzbekistan—Turkmenistan—Tajikistan—Kyrgyzstan—Afghanistan
Third Layer (Attributes)
Urban & Household Facilities
Construction and management of Sanitation and Hygiene facilities
Implementation of Sustainable Development Goal 6 (SDG6)-Water Use
Construction and management of Wastewater Treatment facilities
Construction and management of Drinking Water Supply facilities
Economic Activities
Construction and management of **Irrigation** Systems
Construction and management of **Hydropower** Energy Systems
Water used for **Industrial** purposes
Water-Energy-Food (WEF) Nexus for economic development
Environmental Aspects
Management and Conservation of **Rivers and River Basins**
Management and Conservation of **Mountains** and wider Mountainous regions
Management and Conservation of **Lakes** and Lake Ecosystems
Wider Management and **Ecosystem** Conservation
Natural Hazards
Management and Protection from **Landslides**
Management and Protection from **Floods**
Management and Protection from **Droughts**
Management and Protection from **Avalanches**
Water Governance
Administrative aspects of water management
Policy aspects of water management
Legislative aspects of water management

While Larsen and von Ins (2010) estimate the annual growth rate to be 2.2% for all SCI papers from 1997 to 2006, May reports 3.7% for 1981–1994 (1997), and Landhuis reports a yearly growth rate of 8%–9% (2016). The STM report, which covers 33 119 active scholarly peer-reviewed English language as of August 2018, states that in the recent past, the growth rate has increased to 5%–6% (Johnson *et al* 2018). As a result, we decided to compare four-yearly growth rates: a low estimate of 2.2%, two medium estimates of 3.7%, 6%, and the upper bound of the Landhuis estimate of 9%. Given our data, we performed an exponential regression in order to obtain an estimate of the yearly growth rate of the collected sources in our study and compare this estimate to the growth rates of all scientific peer-reviewed output.

We use relative instead of absolute word frequency to count the frequency of the relevant Dimensions and Attributes. In order to better understand the relative word frequency of each Dimension and Attribute, we employ certain timeframes. The timeframes are divided into 5 year periods, while a simple moving average is calculated for the whole range of the assessed period (1991–2019). The reason for the selection of the 5 years timeframe was due to the finest representation of the Dimensions and Attributes trends within the examined period.

We further create a table where the Attributes with the highest relative word frequency are ranked within a given timeframe of 3 years. The reasoning for narrowing the timeframe to 3 years for the Attributes is the high year-by-year variability, which could not be well attributed in a 5 years range. The Attributes are horizontally selected for all the Dimension groups, while the color-coding adopted in table 1 indicates the origin of the Dimension.

We trace the country origin of the institutes represented by the lead author in each study and we identify the type of organizations, countries, and regions that may be more related to water security challenges in CA. Finally, we explore the sub-discipline and science branches of the journals under which each study was published. We employ the SCImago Journal & Country Rank, which is engineered by Scopus Database. We record up to three sub-disciplines in each journal by prioritizing the ones closer to the content of each journal in case more than three appear. We cluster the various sub-disciplines in four major science branches as social science, physical science, life, and applied science to assess the representativeness of each group.

3. Results

3.1. Frequency and representativeness of dimensions and attributes

We collect 151 articles dealing with water security through the three-layer approach presented in table 2 for the CA region and each country individually. The

Table 2. Representativeness of Dimensions and Attributes.

Distribution per Dimension					
Dimensions	D1: Urb.Hsd	D2: Econ	D3:Env.	D4:Haz.	D5:Gov.
Allocation (%)	36%	71%	85%	52%	11%
Five Dimensions					
7%					
Most Represented Attributes					
Irrigation:30%		Rivers:23%		Industry:17%	
Four Dimensions					
15% (D1-D2-D3: 100%, D4:78%, D5:22%)					
Most Represented Attributes					
Irrigation:16%		Rivers:19%		Ecosystem:17%	
Three Dimensions					
17% (D1-D2-D3: 100%, D4: 0%, D5:0%)					
Most Represented Attributes					
Irrigation:19%		Rivers:19%		Sanitation:16%	
Two Dimensions					
25% (D1:13%, D2:39%, D3:100%, D3:47%, D5:0%)					
Most Represented Attributes					
Irrigation:9%		Rivers:21%		Ecosystem:19%	

Notes: D1:Urb.Hsd = Urban & Household; D2:Econ = Economics; D3:Env. = Environment; 4:HAz = Hazards; D5:Gov. = Governance.

first study to be identified with the water security for CA appears in the year 1997 by indicating the absence of relevant studies during the first 6 years (1991–1996).

The cross-tabulation findings among the five Dimensions are presented by initially describing the option that the same sources are used by more than one Dimension. As shown in table 2, the vast majority of the collected studies cover the Environment Dimension (85%), a significant amount the Economic Dimension (71%), and still quite a few the Hazard dimension (52%) while the Urban & Household stands further behind (36%). The Governance is the least represented (11%).

In turn, we investigate the case where the same source may refer to all five Dimensions. As shown in table 2, the percentage is low but not negligible (7%), while the most frequent Attributes are Irrigation (30%), Rivers (23%), and Industry (17%). The amount of studies is more than doubled (15%) in the case where four Dimensions are used by the same source with the prevalent combination of Environment, Economic, and Urban & Household as the three main components. The fourth component is Hazards (78%) in most of cases and Governance in a few instances (22%). There is again a significant representation of Irrigation (16%), and Rivers (19%) Attributes, while the Ecosystems Attribute (17%) replaces the Industry.

In the same manner, in nearly 1 out of 6 sources, there are references to the three Dimensions of Environment, Economic and Urban & Household with no alternate combination. The representativeness of Irrigation (19%) and Rivers (19%) remains almost unchanged while the Sanitation Attribute (16%) appears. Finally, in 1 out 4 sources, the Environment Dimension prevails in all combinations by pairing mostly with the Hazards (47%) and Economic (39%) and much less with the Urban & Household (11%) and no matching with the Governance Dimension. Irrigation (9%) and Rivers (21%) are still the most frequent, although the former with lower significance than before, while the Ecosystems reappear as a frequent Attribute (19%).

3.2. Relative frequencies and country representation

Figure 2 compares the rise of scientific output in our study and the general increase of research articles. Four estimated yearly growth rates of scientific publications across all disciplines have been obtained from the literature, namely 2.2%, 3.7%, 6%, and 9% and are depicted for the years 1997–2019. The number of studies per year that were collected in our review study is represented as blue dots along the dashed line. The solid blue line indicates the best fit of an exponential regression and yields an average growth rate of 15.7%. Therefore, our results indicate that the scientific interest for water management in CA is growing at a higher pace than the rise of scientific paper output across all disciplines. It is noted that the diagram begins in 1997 due to the absence of relevant sources, as mentioned earlier.

The relevance of each CA country and Afghanistan with each Dimension is further explored in figure 3 and its sections (A) and (B). As noted earlier, the arc lengths of the chord diagram represent how often a CA country or Dimension is mentioned. The country of Afghanistan and Kazakhstan seems to be mentioned the most in figure 3(A) and closely behind are the Tajikistan, Kyrgyzstan and Uzbekistan while Turkmenistan earns the least attention among all

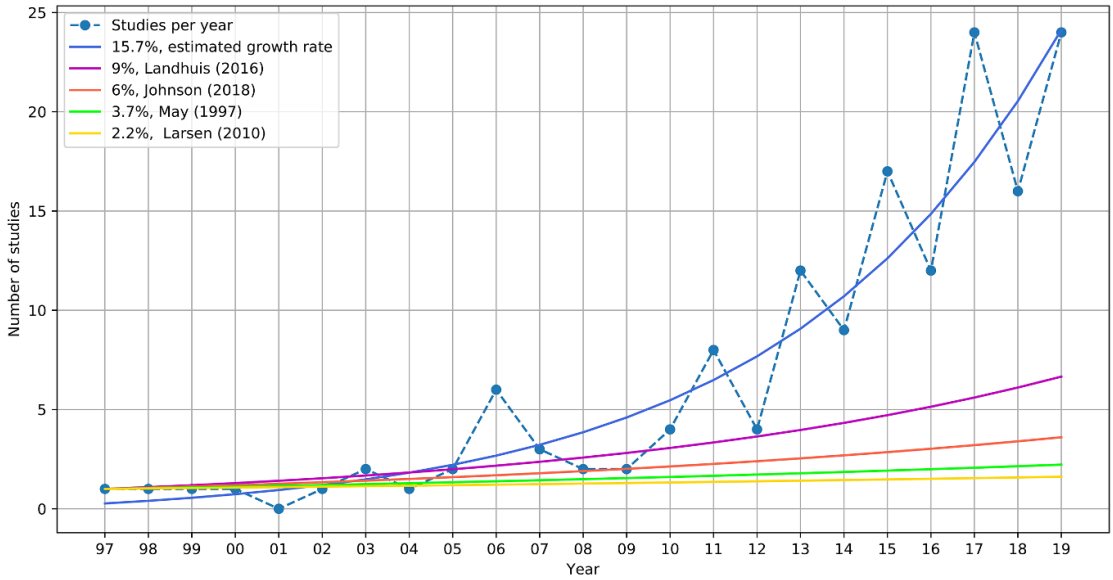

Figure 2. Amount of studies on water security in CA for the period 1997–2019.

CA countries. The Dimensions of Environment, Economics, and Hazards receive the highest attention while the Urban & Household Dimension and Governance show lower visibility.

The connecting nodes between the countries and Dimensions in figure 3(B) show a remarkable association between the Environmental and Economic Dimensions with Kazakhstan and Afghanistan. The above Dimensions seem to be also well linked with Tajikistan and Uzbekistan and, to a lesser extent, with Kyrgyzstan and Turkmenistan. The Hazard Attribute is dominated by Kyrgyzstan with small shares of Tajikistan and Uzbekistan. The Urban & Household and Governance Dimensions capture much less attention than the others with Afghanistan to be the most distinguished country in both cases.

When exploring the most noticeable links between the countries and the Attributes, it appears that the Rivers, Irrigation, Mountains, and Landslides are among the most widely detected among the others. The references to the River Attribute are shared almost equally by the three countries of Tajikistan, Uzbekistan, and Kazakhstan. In the case of Irrigation, Uzbekistan, Tajikistan, and Afghanistan are accumulating most observations while close behind is Kazakhstan. The country of Afghanistan almost seizes the Mountains Attribute while similarly, Kyrgyzstan captures the Landslides. Interestingly, the Water Policy Attribute is getting the attention of nearly all CA countries with Kazakhstan and Uzbekistan to be the most prominent ones.

We further examine the temporal dynamics of each Dimension and Attribute along the years, as presented in figure 4 and its sections (A)–(F). The absence of studies from 1991 to 1997 is also validated in figure 1, while the time horizon is defined from 2001 until 2019. The reason for 2001 as baseline year is due to the adoption of the 5 years timeframe approach mentioned in the methodology section. The first 5 years timeframe period is 1997–2001, which is represented by the year 2001.

As shown in figure 4(A), the Hazard and Environmental Dimensions are being discussed more frequently during the last decade. The Economic Dimension is also gaining importance, albeit at a slower pace than the Hazard and Environment ones. The Urban & Household Dimension was mentioned quite frequently until 2012 but has witnessed a remarkable downfall thereafter. Water Governance is far behind all other Dimensions, and although it seems to have gained some popularity for the period 2001–2004 there is a noticeable decrease afterward.

The results of each Attribute within the Urban & Household Dimension are examined in figure 4(B). It is noticed that from 2003 to 2008, Sanitation and Wastewater reached a peak level but afterward got recessed with low visibility in the last 5 years. The Drinking Attribute also gained quite some attention some years later (2008–2013) but is also following a downward trend more recently. The major factor for the Economic dimension increase is the Irrigation Attribute, which is mentioned far more often than any of the other Attributes, as shown in figure 4(C). For the case of the Environment, presented in figure 4(D), we see that all attributes are gaining pace the last decade with the River Attribute presenting an outstanding upward trend.

The Attribute of Landslides has gained momentum until 2015 in the Hazard Dimension, as shown in figure 4(E), followed, however, by a sharp decrease until nowadays. Instead, the Droughts Attribute has become more popular over the last

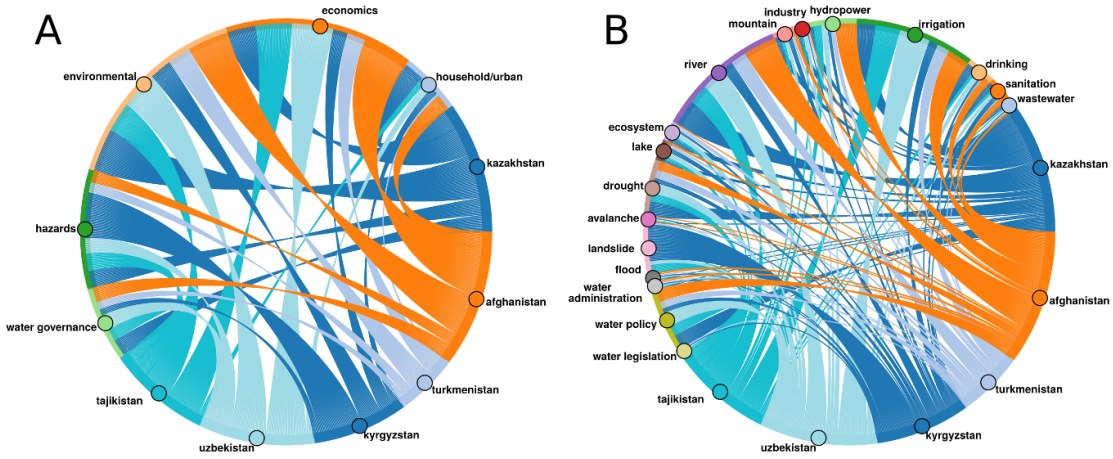

Figure 3. (A, B) Relationship of CA countries and Afghanistan with water security Dimensions.

5 years, while the Flood and Avalanche are not commonly mentioned. In the Water Governance Dimension presented in figure 4(F), the Water Policy Attribute is identified as the main driver, albeit with a major drop since 2004 but still far above the Water Administration and Legislation.

Figure 5 shows a ranking of the most commonly mentioned Attributes within a 3 years timeframe for the whole period of 1997–2019. By conceptually dividing the trends into two chronological clusters (1997–2007 and 2008–2019), it appears that from 1997 until 2007, the Urban & Household and Economic Dimensions were the most representative in each timeframe. In particular, the Urban & Household is almost equally represented by the Sanitation (4) and Drinking (3) Attributes. In the case of the Economic Dimension, the Irrigation Attribute is prevalent (3), followed by Industry (2) in the early years of 1997–2001. The Environment Dimension is of lower significance than the Urban & Household in the first decade with the sole presence of River Attribute (3). In contrast, equal attention is paid to the Hazards Dimension with Droughts (2) and Landslide (1) Attributes mostly mentioned. The Policy attribute that represents the Governance Dimension also appears continuously from 1999 until 2007.

The situation is reversed for Hazards in the period 2008 until 2019, where the Landslide and Drought Attribute become nearly twice as frequent in the literature than in the previous decade. A similar twofold increase appears for the Environment Dimension, where the River Attribute shows up in each timeframe. These increases seem to come at the expense of the Urban & Household Dimension, which becomes absent from 2014 and onwards. A lower but still noticeable underrepresentation also comes for the Economics Dimension. The Irrigation Attribute retains its visibility and, to a lesser extent, the Hydropower; however, the Industry is faded out. The Attribute of Policy also appears in the second timeframe by indicating its continuous frequency throughout the entire period.

In the case of the country and regional representation, Europe (43%) seems to host most of the institutes of the lead authors, as presented in figure 6. The United States appears to host a considerable number of the relevant institutes (17%) while interestingly, an equal amount is traced in the CA region. China appears also to share a proportion of the hosting institutes (15%) and, to a much lesser extent, South Asia and East and Southeast Asia.

The universities receive the lion's share (54%) as the prevalent type of institutes to represent the lead author, while in about 1 out of 3 cases, there are research organizations. The portion of associations/organizations/networks is lesser but noticeable (10%), and of consultancy and firms is negligible (1%). The physical sciences (43%) appear to dominate the discipline background of the hosting journals while applied (26%) and life sciences (19%) are also well observed. The social sciences receive the least attention (12%) among all others.

4. Discussion

4.1. Environmental aspects and technocentric solutions

The research review from 1991 until 2019 has revealed that there was a complete absence of relevant literature on water security for the first 5 years (1991–96). This reflects the general development of the water security concept, which has only gained popularity in the 21st century. The apparent increase of literature, especially from 2012 and onward, is a strong indicator of the scientific interest in the relevant literature towards the notion of water security in the region. The comparative growth trend of the literature review with the relevant sources reveals a higher

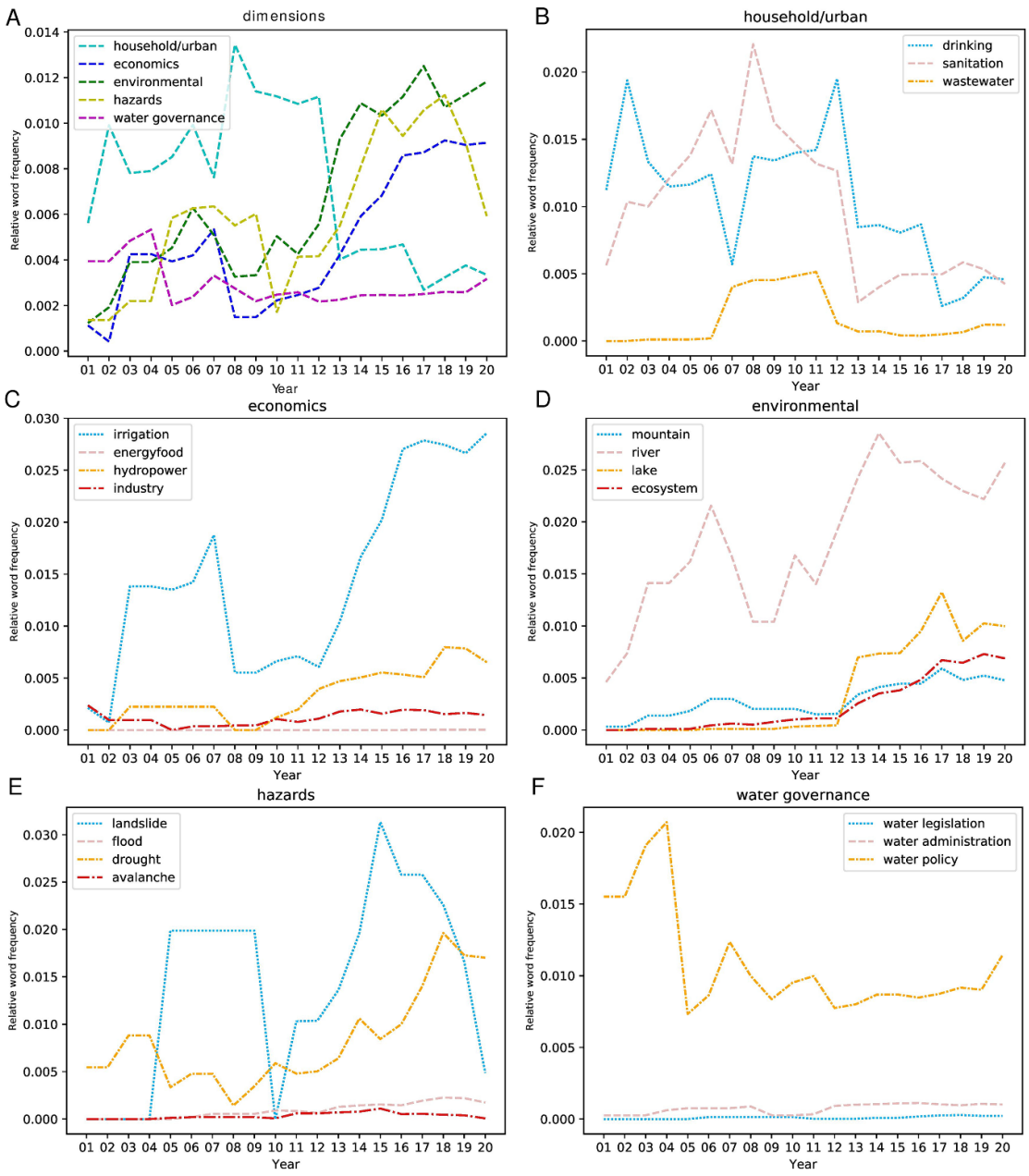

Figure 4. (A)–(F) Relative frequencies of Dimensions and Attributes for the period 1997–2019. The *y*-axis shows relative word frequency, i.e. the fraction of word occurrence in relation to the total number of words.

Figure 5. Ranking of the relative word frequency of Attributes within predefined 3 years timeframe for the period 1997–2019.

increase in water security studies in CA. The increase could be attributed to the overall interest of water security notions worldwide; however, the complexity of transboundary waters and Soviet legacy may be an additional motivation to explore security issues for the relevant region.

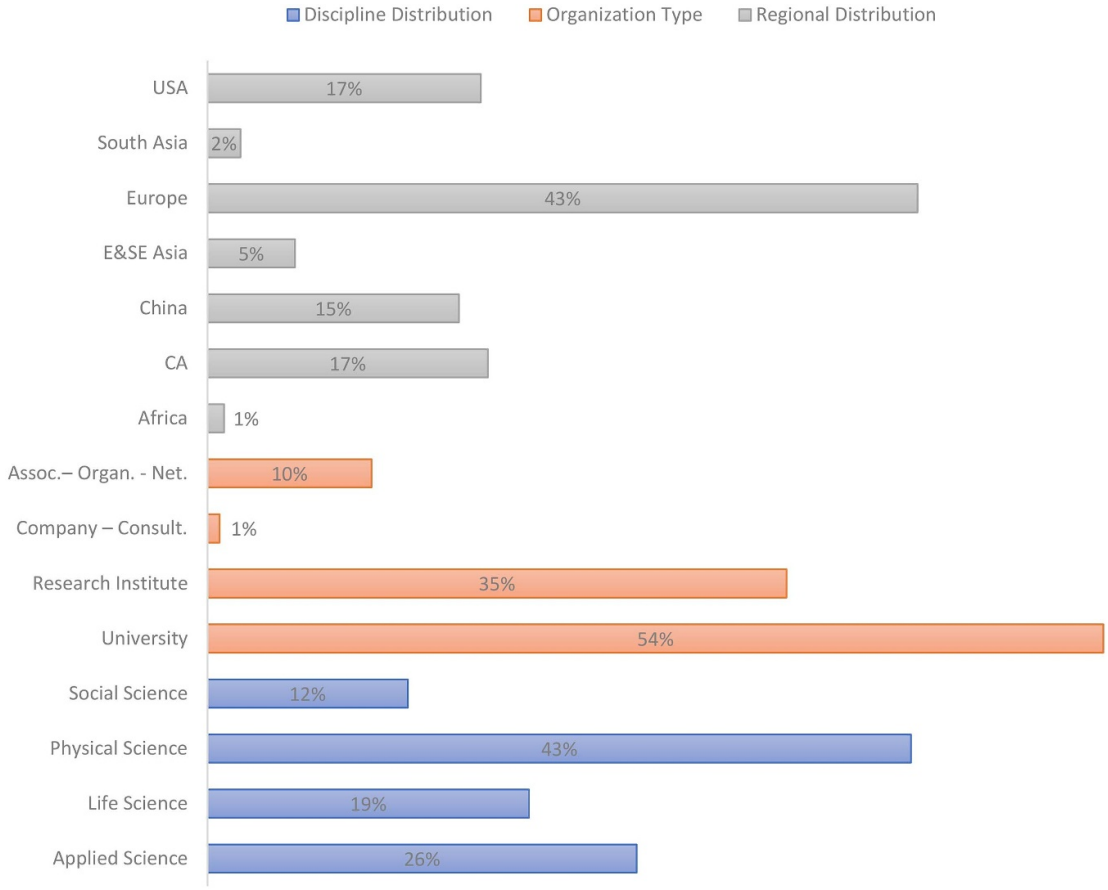

Figure 6. Represented country of lead authors, type of institute and science branches.

Our analysis shows that the environmental-related aspects are represented in most of the collected literature and are frequently combined with the hazard, economic, and urban & household perspectives. When exploring the sources which refer equally to all 5 Dimensions, we notice that high attention is paid on the natural facets of water security and especially on climate resilience studies and infrastructural projects that could mitigate impacts on rural communities and fragile riverine ecosystems (Stucki and Sojamo 2012, Stewart 2014, Narama *et al* 2018, Zheng *et al* 2019). It is mostly technical studies that propose engineering-based solutions to improve river basin management and human livelihoods, often in rural areas.

The combination of the Economic, Environment, and Hazard Dimensions also accentuates the role of river basin management in climate change. There are many references on the climate change effects of the glaciers situated in Pamirs, and moreover, Tien Shan mountains and the environmental implications on the hydrological balance of the region is phrased in many sources (Granit *et al* 2012, Schluter *et al* 2013, Wang *et al* 2013, Krysanova *et al* 2015, Jalilov *et al* 2016, Kapitsa *et al* 2017, Hoelzle *et al* 2017, Pueppke *et al* 2018, Zhang *et al* 2019, Zheng *et al* 2019). The long term repercussion of ice melting on the water security of CA has been stressed, especially in the dry seasons where hydrological balance is driven mainly by snow and glacier meltwater rather than from precipitation (Granit *et al* 2012, Sorg *et al* 2014, White *et al* 2014). Different studies propose the introduction of technical approaches for the mitigation of runoff reduction downstream due to the growing water demand and climate change impacts in upstream countries (Schluter *et al* 2013, Rudenko *et al* 2013, Stewart 2014, Guo *et al* 2018, Zhupankhan *et al* 2018, Jiang *et al* 2019).

The adoption of ecological engineering approaches is also suggested for a shift from the high water-consuming agricultural sector to conservation practices for the avoidance of other major destructions as in the case of Aral Sea (Rudenko *et al* 2013, Djanibekov *et al* 2013, Wegerich *et al* 2015, Pueppke *et al* 2018). Other studies refer to the risk of geopolitical tensions in transboundary river systems due to irrigation mismanagement and absence of environmental flows by suggesting technical solutions to mitigate the risk factors (Chan 2010, Karatayev *et al* 2017, Ahmadzai and Mckinna 2018).

A similar technocentric approach occurs with the studies mentioning the Environmental together with the Economic and Urban & Household Dimension. Many cases emphasize the need for better sanitation

facilities with technological means that could also ameliorate water quality and relevant environmental services (Semenza *et al* 1998, Biran *et al* 2005, Franz and Fitzroy 2006, Gungoren *et al* 2007, Herbst *et al* 2008, Gon *et al* 2014, Bekturganov *et al* 2016, Himes 2017, Uddin *et al* 2019). The Sanitation attribute is highly associated with the national health and hygienic strategies set by the Sustainable Development Goal No.6 (SDG 6) on Clean Water and Sanitation, which is nowadays included in the policy agenda of all CA countries (Abdullaev and Rakhmatullaev 2016, Chukayeva and Akzharov 2016, Ahmadzai and Mckinna 2018, Huan *et al* 2019).

Although the access to drinking water and sanitation is prioritized along the region, however, the safely managed drinking water coverage and sewage management vary among CA countries as per the WHO/UNICEF Joint Monitoring Programme for Water Supply, Sanitation, and Hygiene (JMP, https://washdata.org/). The safely managed drinking water services (SDG 6.1) for the year 2017 (latest records) are way better in Turkmenistan (94%) and Kazakhstan (90%) than Kyrgyzstan (68%), Afghanistan (67%), Uzbekistan (59%) and Tajikistan (48%). There is higher homogeneity among CA countries in the case of basic sanitation services where the accessibility rate appears to be over 90% except for Afghanistan (43%).

4.2. Governance and national interests

The Governance Dimension is hardly combined with any other while the overall representation is rather low. The governance and social elements of water security seem to be overlooked in favour of more technically applied options pursuing human well-being and environmentally sustainable dividends. A recent review focused on water governance in CA also showed a lack of genuine literature on these political aspects, in particular at the national level, and a focus on technical and managerial elements (Sehring 2020).

The underrepresentation of the governance factors in our review reflects the dominant approach to water security in CA rather than an overlooking of the terminology from our side. The selection of the relevant Attributes (legislation, administration, policy) may not entirely cover the governance framework, while technically oriented studies could use similar terminology. This is probably the case with the Policy Attribute that is well documented from 1997 until 2019 in many studies, as shown in figure 5.

By exploring, however, the content of the relevant studies, it appears that the policy and the other selected keywords (administration, legislation) are pertinent to the governance concept. For instance, the issue of water conflicts in CA due to the lack of appropriate water policies and transboundary governance was addressed (Abdolvand *et al* 2015, Lee and Jung 2018). The weak institutional capacity to produce adequate water policy framework for better governance was also underpinned (Abdolvand *et al* 2015, Himes 2017). The major administration vacuum created after the collapse of the USSR was highlighted by mentioning the imminent need for better basin planning and management (Wegerich 2011, Lee and Jung 2018). It was pointed out that the national line ministries and relevant water authorities have limited expertise in basin planning and administration, especially on sub-basin level by overlooking the needs of local communities (Amirova *et al* 2018, Xenarios *et al* 2019c). There are also arguments on the inadequate water legislation (water codes) while the bureaucracy and lack of transparency of the implementing agencies limit the efficacy of the relevant policies (Karatayev *et al* 2017, Zhupankhan *et al* 2018).

Still, however, even if accepting that there is a potential overlapping of the Policy and probably Administration Attributes, the overall representation of governance aspects is lower than the others. It was only the last four years where the downward trend of Urban & Household was brought in the same levels with the Governance as shown in figure 3(A), whereas the Economic, Environmental, and Hazards are far ahead. The underrepresentation of governance could also be inferred in figure 6 where the social sciences seem to be overlooked in favour of the physical, applied, and life sciences in the journals hosting the collected literature of our study.

We accept the assumption that the social science studies are in general unrepresented among other science branches (Johnson *et al* 2018). Still however, the appearance of the social aspects on water security studies in CA is scarce. As Sehring (2020) notes, 'questions like how and why governments decide on which water policies or how different state, non-state, and international actors are involved or marginalized in decision-making, remain understudied' (p 4).

The country-specific analysis for each Dimension and Attributes offers valuable insight into the particular priorities and targeted objectives of each CA country and Afghanistan, as suggested by the literature. The flows may not offer exact quantitative figures; however, they could well signify the inclination towards specific water interests by each country. The overall outlook between the CA countries and Afghanistan towards water security notion, do not reveal clustering or homogenous behaviours among the countries. Each country seems to pursue individual objectives prioritized as per the national interests and motives. The reasoning behind these attitudes should be further explored to better coordinate water security perceptions and initiatives within the region.

The organization type and country origin of the lead authors presented in figure 6 can hardly detect the potential influence of country, regions, and institutes towards the formulation of a water security

concept in CA. For this reason, we avoided the development of exploratory statistical techniques to investigate potential relationships. The findings just indicate that European universities and research institutes seem to be more interested in the implications of water security in the CA region. A previous study has attempted to identify the potential associations between research institutes and water security studies in CA by showing that many scholars of CA origin reside in Europe by however conducting research for the region (Xenarios *et al* 2019c). Still, though, further analysis needs to be done on the potential drivers and motives to incentivize the literature development towards water resources management and security in CA.

5. Conclusions

Our bibliometric review assessed the potential resemblances and differences of water security in CA as well as the individual components (Attributes) supporting these notions. The literature search indicated that water security in CA focuses mainly on the protection of the natural environment, economic growth, and mitigation of hazards through technological interventions. The Dimensions of water security represent specific concerns of water resources to be confronted with technical solutions, without incorporating governance elements and overarching perspectives that are needful in policy-making processes.

For example, the Environmental Dimension showed the major concern of CA countries towards the water availability in transboundary rivers; it is also a dimension where the inclusion of water governance within and among CA countries is necessary. There is, however, lack of effective interregional institutions to monitor potential uneven water sharing between CA countries (Karatayev *et al* 2017, Zhupankhan *et al* 2018).

The unilateral focus on technical-related practices will hardly be sufficient for a region that has to govern complex systems of transboundary water resources through principles of efficiency, sustainability, and even distribution. A cross-disciplinary perspective could help to better accommodate water complexity and security in CA by balancing the natural environment as well as governance principles across sectors.

The peculiarities of CA should also be considered by contextualizing water security in relevance to the policy agendas of each country and cooperation potential in the region. Although there is some transboundary cooperation on water resources among the CA countries, the notion of water security is still related to uncoordinated and unsustainable management, resulting in conflicts of interests (Murzakulova *et al* 2019).

The broad concepts (Dimensions) and specific priorities (Attributes) set by each country or a group of CA countries on water security interests need further attention. The prioritization of different water security aspects between each CA country may not be far apart, however, they may become a source of conflict if not cautiously addressed in the near future.

The current review study draws inferences from research-based documents on the conceptualization of water security in CA, which may be distant from the actual policy discourse in the region. It is, however, acknowledged that the literature review can become a precursor of the actual future discussions and the policy agendas on the security of water resources in CA.

Data availability statement

The data that support the findings of this study are available upon reasonable request from the authors.

Acknowledgments

The third author acknowledges the invaluable support of Qilu Scholar Grant provided by Shandong University (ref: 61060089963026) in the completion of this study.

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