ARTICLE IN PRESS

STOTEN-160500; No of Pages 12

Science of the Total Environment xxx (xxxx) xxx

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Review

Sustainability of water transfer projects: A systematic review

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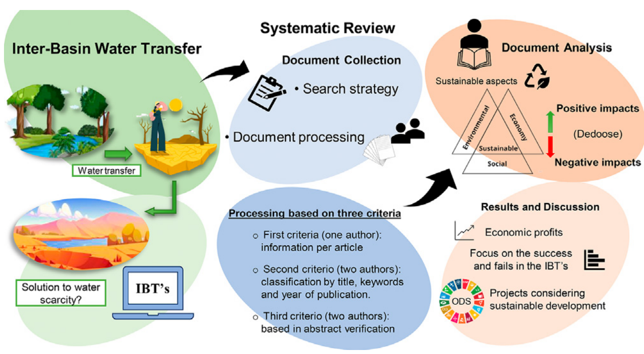
HIGHLIGHTS

- A systematic review and analysis of IBTs is provided at a global scale.
- IBT projects inherently impact all three pillars of sustainability.
- Results show two negative impacts for each positive impact.
- IBTs have direct implications on achieving the UN sustainable development goals.

GRAPHICAL ABSTRACT



ARTICLE INFO

Editor: Ouyang Wei

Keywords:
Inter-basin water transfer
Sustainable impacts
Global scale
Literature review
Sustainable development goals

ABSTRACT

Inter-basin water transfer projects (IBTs) have significantly increased in number in recent decades due to the unremitting need to solve the problem of global water imbalance. However, given the complex challenges inherent in implementing and maintaining IBTs, there is a need to characterize the multi-faceted aspects of sustainability (or unsustainability) that result from these megaprojects. Through a systematic review of the literature, we sought to identify and characterize the positive and negative impacts that most often influence the sustainability of IBTs, focusing on impacts within the environmental, social, and economic pillars of sustainability. Based on an eligibility criterion, the systematic review selected 68 documents out of an initial total of 1567 for information quality analysis and content evaluation. The qualitative coding of the documents allowed us to characterize the landscape of impacts that result from IBTs across the three pillars of sustainability. The study findings revealed that the most frequently coded positive impacts related to the environmental pillar of sustainability, while the most frequently coded negative impacts related to both social and environmental pillars. In addition, the most frequently coded positive impact overall related to the economic benefits generated by the IBTs. Through a critical analysis of the study findings, we provide an assessment of future IBTs with a focus on the UN sustainable development goals.

Contents

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http://dx.doi.org/10.1016/j.scitotenv.2022.160500
Received 12 August 2022; Received in revised form 21 November 2022; Accepted 21 November 2022
Available online xxxx

Please cite this article as: M. Faúndez, H. Alcayaga, J. Walters, et al., Sustainability of water transfer projects: A systematic review, Science of the Total Environment, http://dx.doi.org/10.1016/j.scitotenv.2022.160500

1. Introduction

Although water has always been an essential resource for human development and ecosystem conservation, this reality has only become more apparent in recent decades due to population growth, economic growth, and climate change. These realities pose a major problem for ecosystems within river basins, as growing trends in consumption continue to deteriorate watersheds and aquatic systems (Sheng et al., 2020; Tien Bui et al., 2020). However, water availability also depends on the climatic zone of the region, which is related to the topography and geology of the area (Pereira et al., 2009). The spatial variability in precipitation is clearly displayed in Fig. 1, which the average annual global rainfall between 1901 and 2020 for different regions of the planet… We see that there are extreme cases in North Africa, along with some sectors of South America and south-central China, which show a considerable difference in precipitation levels compared to places such as the Amazon in Brazil, southern China and most areas in Southeast Asia. This global disparity in precipitation affects both the human population and the natural ecosystem. Adapting to this natural effect has led to the search for technical solutions that solve the lack of water availability amidst growing demand.

Water scarcity is the lack of water availability to cover water needs for human and environmental use (Grafton et al., 2014). This can be measured in many ways, with one of the most common metrics being water stress indicators. Fig. 2 summarizes the global water risk by country, based on water quantity and quality data obtained from the Global Resource Institute (WRI). This represents the difference between water availability and demand for human and environmental use, scored from 0 to 5 on an ascending scale of water risk. There are cases (e.g., China) where the main problem is the high population density and the increasing use of water, which exceeds the current availability generating an extremely high risk of scarcity in some sectors. Conversely, there are places, such as North and South Africa or southern America, that present deficiencies in the availability of water from the regions (Fig. 1) and geological and geographical factors, generating extremely high levels of water risk, as indicated in Fig. 2.

A range of solutions has been sought to solve the growing demand for water worldwide. These solutions have been studied, such as water desalination (Kumar R et al., 2022; Manju and Sagar, 2017; Meerganz von Medeazza, 2004; Tan et al., 2022), integrated and sustainable use of water (Alberti et al., 2022; Issaoui et al., 2022; Uhlenbrook et al., 2022) as well as inter-basin water transfer projects (IBT) projects (Sheng et al., 2020; Shumilova et al., 2018; Zhang et al., 2015; Zhuang, 2016). Increasingly, IBTs are emerging as a possible solution to water scarcity.

Water transfers between basins have been used for thousands of years to alleviate water scarcity issues or provide water to areas where it is needed (Zhuang, 2016). The first records of water transfer projects were in ancient Babylon and the Egyptian civilization (Meador, 1992; Zhuang, 2016). IBTs have since been proposed as a solution to water shortages due to periods of drought, climate change, population growth, and environmental constraints. These engineering works are used to increase water supply for agriculture and residential, industrial, and hydroelectric generation, among others (Zhang et al., 2015), to alleviate the imbalance between supply and demand of water resources based on the high spatial variability of water availability, which is seen throughout the globe (Fig. 2).

IBT projects aim to provide water through a collection system from a donor basin, a transfer system that transports water, and a delivery system, which usually has a reservoir to receive the water in the receiving basin and then distribute it to the receiving agents. In 2015, >160 major IBT projects were implemented or under construction in 20 countries, including the United States, Canada, Australia, India and China (Sheng et al., 2020; Shumilova et al., 2018). Currently, there are a large number of IBTs that have been the subject of numerous studies (Matchaya et al., 2019; Mokorosi and van der Zaag, 2007; Morote et al., 2017; Wang et al., 2021). Within these projects, some stand out above the rest by virtue of their significant environmental and socio-cultural impacts resulting from project, execution, operation and maintenance. Within the literature we find many examples of negative, social, environmental, and economic impacts resulting from IBT projects, such as: i) The Central Arizona Project (CAP) in the USA, which presented considerable economic problems resulting from underutilization as a result of high water tariffs compared to other water sources (Cheng, 2006; Hanemann, 2002; Yan-Jun, 2008); ii) The Quebec Water Transfer Project in Canada, which imposed significant socio-environmental impacts on indigenous populations as a result of relocation and the anthropic pressure on tribal lands (de Queiroz and Motta-Veiga, 2012; Yan-Jun, 2008); and iii) the National River Linking project in India, which lost important terrestrial habitats to flooding, thereby reducing the local diversity of flora and fauna (Ghassemi and White, 2007; Zhuang, 2016). However, perhaps the most notable exemplar of IBT impacts is the South-North Water Transfer Project (SNWTP) in China, known as the largest hydraulic project in the world. Despite its large investment, SNWTP was not exempt from environmental, social and economic problems such as the high price of transferred water or the significant decrease in the flow of the Hanjiang River resulting from high water extraction (Sheng et al., 2020; Zhuang, 2016).

Current water needs require balanced development among the environmental, social and economic pillars of sustainability. In 2015, the United Nations developed the sustainable development goals (SDGs) as a universal call to promote actions that, beyond fulfilling the primary purposes of ending poverty, protect the planet and maintain a balance between the three pillars of sustainability (United Nations, 2018). Within the framework of this research, the definition of a successful IBT project is ultimately one that is sustainable, where, per the definition by the Brundtland Report (1987), "sustainable development is what meets the needs of the present

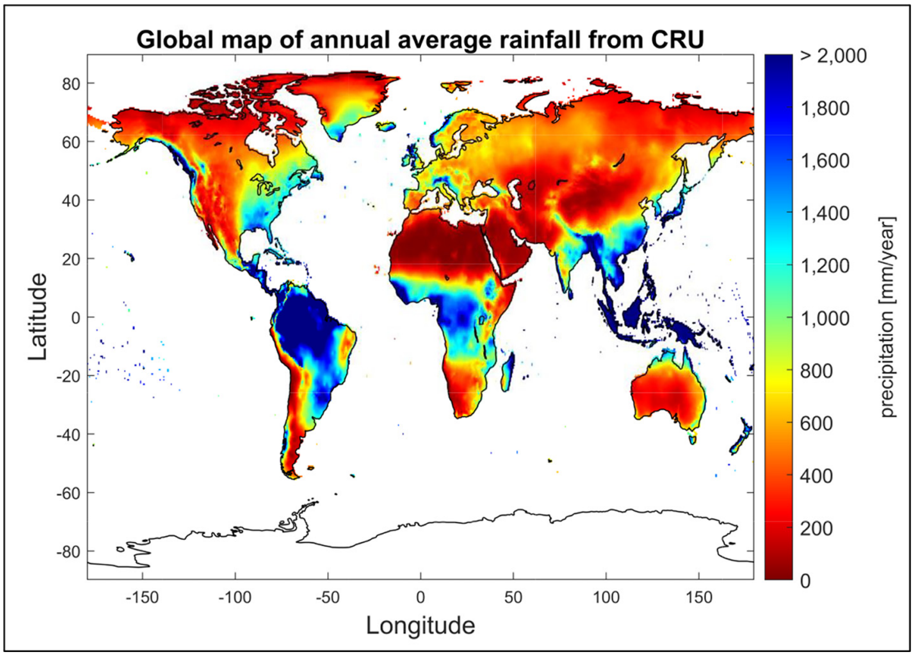

Fig. 1. Global map of annual average rainfall based on The gridded Climatic Research Unit (CRU) Time-series (TS) data version 4.05. Data range from 1901 to 2020 and are provided on high-resolution grids (0.5 × 0.5 degrees). https://catalogue.ceda.ac.uk/uuid/c26a65020a5e4b80b20018f148556681 (last access: 11/08/2022).

generation without compromising the ability of future generations to meet their own needs" (Brundtland, 1987; Bastida-Molina et al., 2022; Bonnedahl et al., 2022; Sarkodie, 2022). A sustainable IBT project therefore continually meets its technical and economic objectives while promoting a contribution to the social environment without generating permanent impacts on the ecological environment.

Based on the above, our general research hypothesis is that the success or failure of an IBT can be evaluated in terms of sustainability as a means to identify the most influential components within project design and execution, elucidating strategies and anticipated impacts for future projects. Using a systematic literature review approach, our research aimed to identify and characterize the different social, environmental, and economic

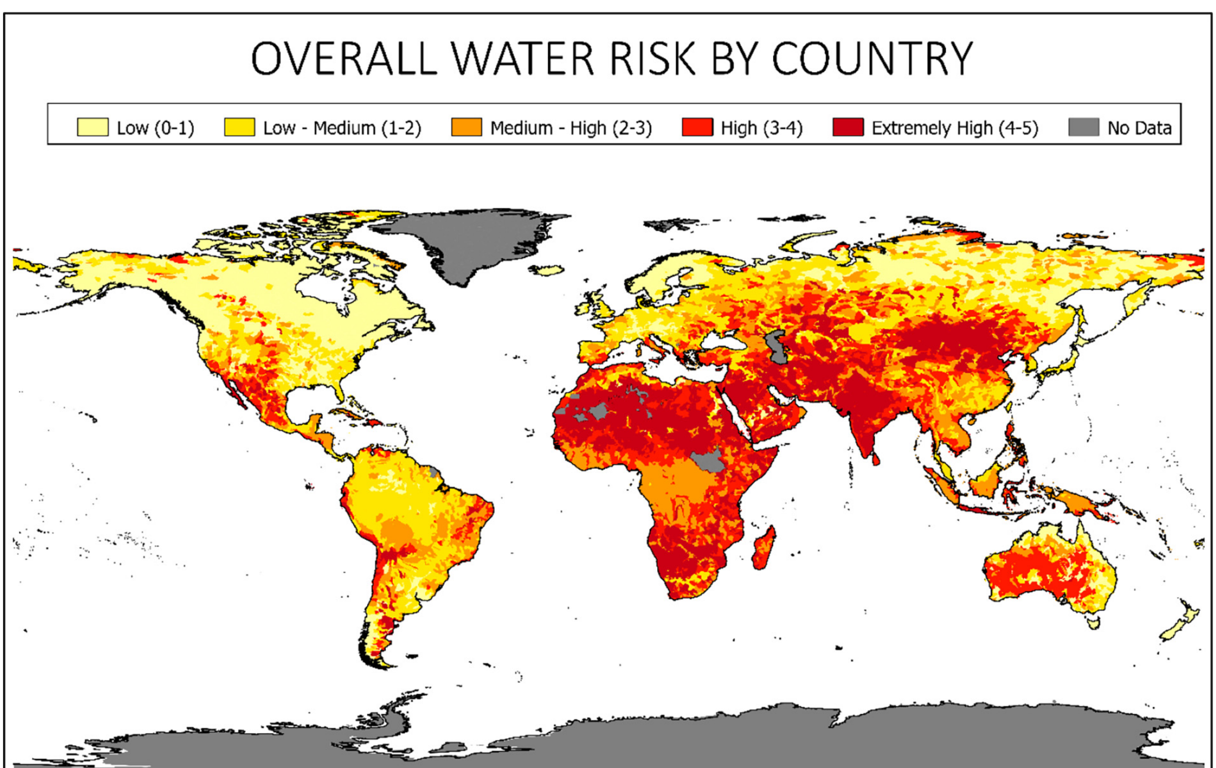

Fig. 2. Global map showing the overall water risk baseline obtained with data from the World Resource Institute (WRI). Data Source: Aqueduct Global maps 3.0, 2019. https://www.wri.org/data/aqueduct-global-maps-30-data (last access: 11/08/2022).

impacts of large-scale IBTs projects around the world. In doing so, this work aimed to evaluate the current sustainability landscape of IBTs to inform policy and practice that maximizes the likelihood of environmental, economic, and social sustainability of future water transfer projects.

2. Material and methods

The research methodology used in this study consisted of the following three stages for document analysis shown in Fig. 3: (1) Document collection and systematic analysis; (2) Document processing based on three inclusion criteria; and (3) Document analysis. In the first stage, document collection was performed for the systematic review, corresponding to the first sample of documents gathered prior to the screening phase to obtain an exhaustive list of IBT literature based on a keyword search equation. The second stage entailed processing these documents based on three eligibility criteria which matched the results of the first stage with the objectives of the investigation. Finally, the third stage focused paired an assessment of information quality with a detailed content analysis aimed at rigorously extracting information from the documents related to the three pillars of IBT project sustainability. We describe each stage of this research process in more detail below.

2.1. Stage 1: search strategy for systematic literature review (SLR)

A systematic literature review (SLR) aims to provide an exhaustive and objective synthesis of the available evidence, in which a determination and extraction of quantitative and qualitative aspects of original studies are performed. In this study, an SLR was developed according to the Cochrane guidelines called Preferred Reporting Items for Systematic Reviews and Meta-Analyses (Page et al., 2021), using three selection criteria: (i) Duplicates; (ii) Title and keywords; and, (iii) Abstract and full-text. First, the databases were defined, corresponding to Web of Science and Scopus. The publications were imported and managed in Microsoft Excel 2021 (from here on, referred to as Excel) during the screening process. The database search used a Boolean-based equation defined as: *Inter-basin water transfer OR Inter-basin water diversion OR Water transfer OR integrated water resource management) AND Sustainability OR Sustainable.* Specific IBT technologies or techniques (i.e., piped distribution or bulk water supply) were not explicitly referenced within the search equation in order to ensure a broader survey of global water transfer projects. Documents written in English and Spanish were selected only, requiring that abstracts and keywords were written in English.

In terms of the search equation, the keywords were categorized into two groups. First, the definition keywords represented the concept of water transfer between basins associated with an engineering project. Second, the objective keywords represented the focus of the documents to include in the analysis of this study, corresponding to positive and negative impacts on the three pillars of project sustainability. The keywords used in this research regarding the definition of IBTs were: inter-basin water transfer; inter-basin water diversion; and, water transfer. Finally, the keywords referring to more general aspects of project sustainability were: integrated water resource management; sustainability; and, sustainable. The search equation was formulated to obtain literature that considered the transfer of water between basins in conjunction with the aspects of sustainability, so the use of the "AND" connector represented the intention to incorporate sustainability dimensions into related studies on water transfer.

2.2. Stage 2: screening and eligibility criteria

Literature included in the systematic review were constrained to works published between 1990 and 2021. The identified documents were selected based on their title, keywords, and abstract for both databases. In addition, they were filtered by document type, including five types: article, review articles, conference paper, proceedings paper, and early access (this dataset will be called documents).

The first criterion of the SLR was the elimination of duplicates between the two databases. The results obtained in the bibliographic search were exported from the web pages of Scopus and Web of science as a CSV file, including the following information: title, keywords, abstract, authors, year of publication, DOI, the language of the official document, and journal information. For the first criterion, title, authors, year of publication and journal were used. They were classified and compared in alphabetical order of titles and grouped by year of publication.

The second criterion was the classification and deletion of documents according to title and keywords. The objective of this criterion was to classify documents using a numerical system based on the relationship between their title and the central theme of the research, corresponding to water transfer projects between basins. The used classification system is detailed as follows:

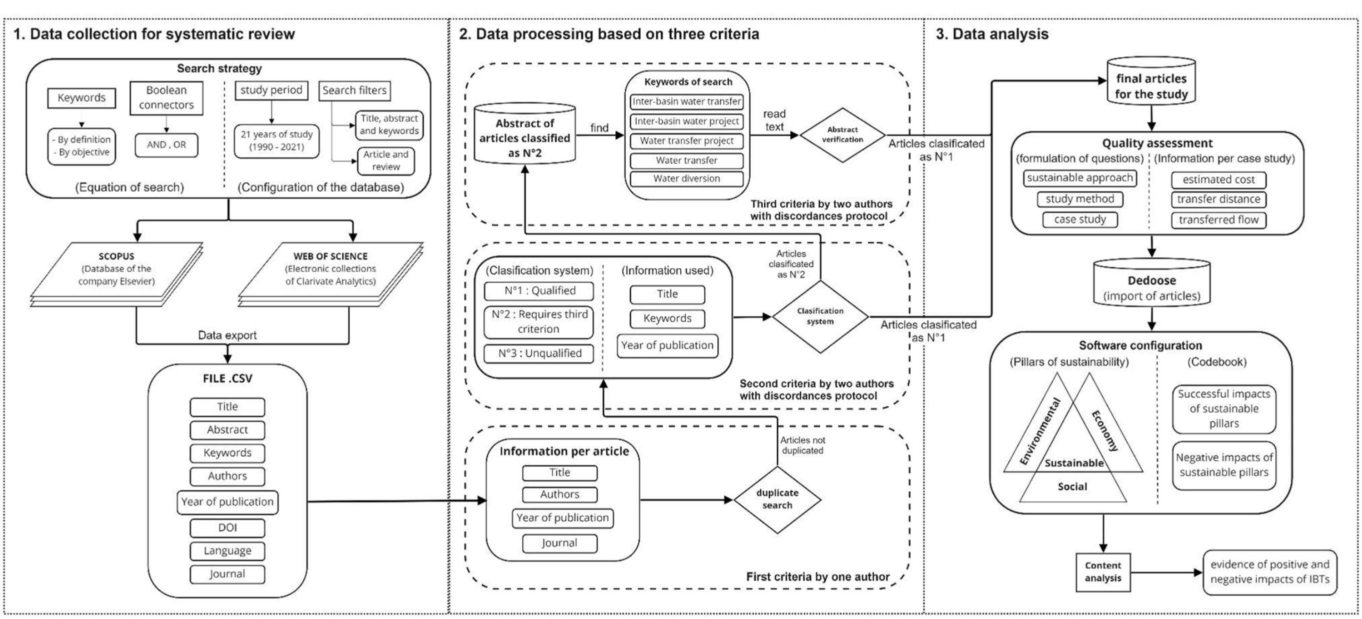

Fig. 3. Methodological diagram used in the research, according to three stages: 1. Data collection for systematic review; 2. Data processing based on three criteria; 3. Data analysis.

- Number 1 (n°1): Documents that refer to water transfer in the title textually and without confusing interpretation.
- Number 2 (n°2): Documents that do not refer to water transfer in the title but relate to water transfer in the abstract.
- Number 3 (n°3): Documents not directly related to water transfer in the title and not related to the research topic.

The keywords were used to facilitate an unbiased choice of documents that do not refer to water transfer in the title. This criterion was carried out by two authors (Manuel Faúndez (MF) and Marco Soto (MS)), independently, following a protocol of discordances. For those documents where the classification did not coincide, the arguments and assessments to reach a mutual agreement were presented by both parties. An agreement was reached through a statement of criteria and arguments between the two parties in the case where the criterion yielded documents that were ambiguously related to water transfer. The third criterion was used to classify all documents in category two of the second criterion (title and keywords). Those documents that did not refer to water transfer explicitly in the title were subjected to the third categorization criterion where, after reading the abstract, the eligibility process was completed. The classification was automated using MS Excel, searching for at least one of five keywords considered a minimum requirement. The words chosen were: inter-basin water transfer; inter-basin water project; water transfer project; water transfer; and, water diversion. Documents that did not contain any of these five words in the abstract were automatically discarded, classifying them as Number 3.

2.3. Stage 3: data analysis

All the final documents were subjected to a quality assessment that evaluated the potential informative contribution of the studies selected in the SLR. A model was created based on the bias risk assessment typically used in meta-analysis and systematic review articles, using a design of three categories of answers (yes, no, and unclear) that addressed a series of questions for study relevance (Petermann-Rocha et al., 2022; Xia et al., 2021; Zare Sakhvidi et al., 2022). The questions were: (1) Does the study take a social perspective on sustainability? (2) Does the study take an economic perspective on sustainability? (3) Does the study take an environmental perspective on sustainability? (4) Is it a quantitative study? (5) Is at least one of the study cases in the document considered a transfer megaproject (as defined by Shumilova et al. (2018)? "yes" response was considered as a highly informative study, "no" for a low-informative one, and "unclear" when the information provided is not sufficient to classify the study within the two previous responses. Two authors performed the analyses in cases where a clear response was not evident. Finally, the evaluated sample determined the document's quality with respect to the information sought by this research to extract social, environmental and economic impacts that affect the sustainability of water transfer projects. We considered a representative sample for the investigation in case to obtain >50 % of "yes" responses (on average).

The qualitative coding analysis of sustainability impacts was facilitated with the qualitative analysis tool Dedoose (Dedoose, 2021). The content analysis, performed by the qualitative coding of the documents, aimed to identify and classify the positive or negative impacts – whether social, environmental, or economic – generated by the IBTs. These impacts, whether positive or negative, were assumed to exist in isolation; that is, no correlations or indirect connections were considered between positive and negative IBT project impacts.

A codebook of parent and child codes was developed to characterize and store text excerpts containing the positive and negative impacts of the IBTs. The codebook used in the research was developed deductively by the five authors based on anticipated impacts and the relevant aspects

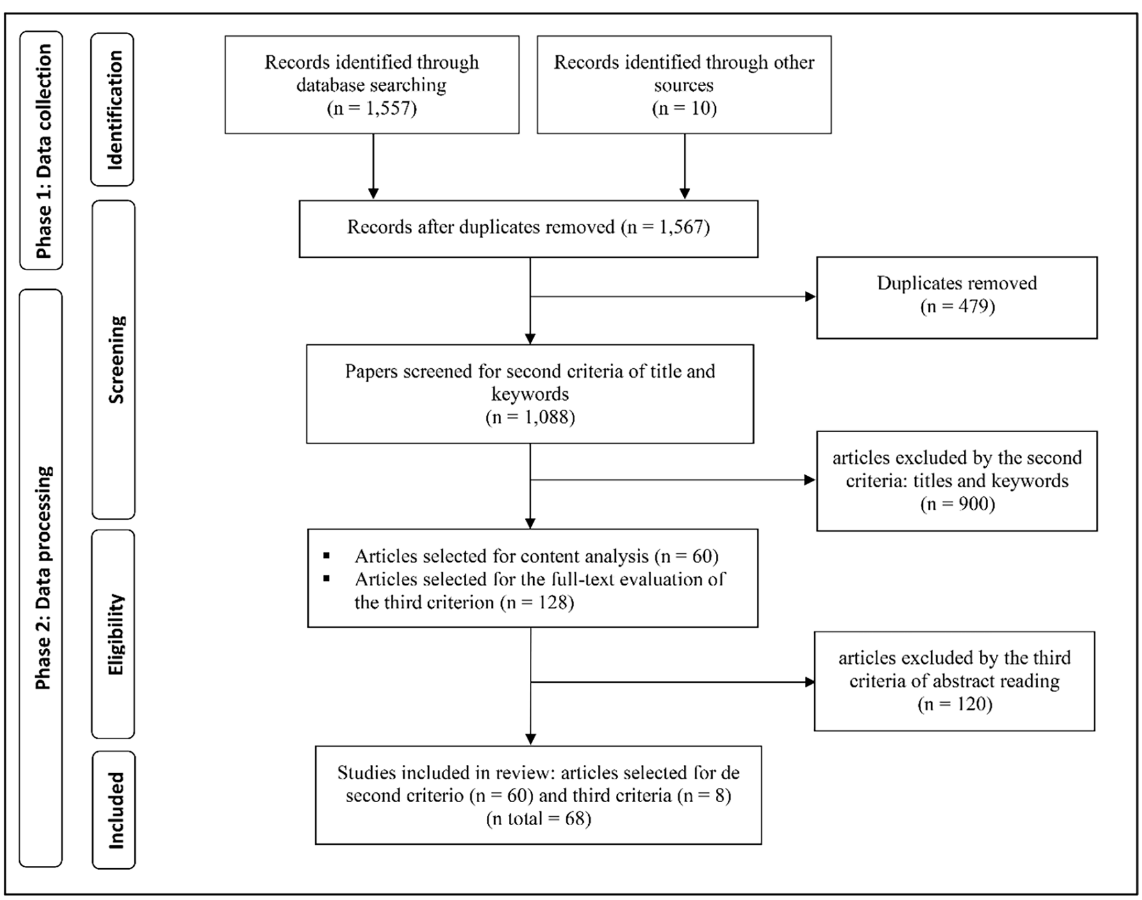

Fig. 4. Report Elements for Systematic Literature Reviews (PRISMA) with the selection of documents included in this research.

of social, environmental, and economic sustainability for engineering projects. The documents were evaluated individually with a focus on existing, proposed or terminated transfer projects that would provide information on actual project impacts, demonstrable on the basis of empirical evidence provided by the analyzed documents or referenced documents where an impact is cited. To this end, a three-level codebook was generated: i.) positive or negative IBT project impact(s); ii.) the sustainability pillar to which it refers (environmental, economic, or social); and finally, iii.) the topic of the project referenced in the coded text. We present an example of this coding process in Table S1 in Supplementary Materials.

3. Results

Below we provide a summary of the results obtained from the aforementioned stages of the SLR employed in this study, as well as those that emerged from the content analysis of positive and negative impacts from IBT projects.

3.1. Systematic literature review

707 documents were obtained via Web of Science, 850 documents were obtained from Scopus, and 10 were identified in other sources. This provided 1567 documents in total ranging from January 1990 to November 2021. The first criterion for eliminating duplicates reduced the documents from 1567 to 1088 (479 duplicates, Fig. 4). Years 2018, 2019, and 2020 produced the highest number of documents, 99, 98, and 112 documents, respectively. Documents from 1990 to 2000 contributed only 22 documents (Fig. 5).

The second criterion classified the documents in the previously mentioned numerical format of three options (n°1, 2 and 3), based on document titles, keywords, and abstracts. A total of 900 documents classified as n°3 (unqualified) were rejected (outside the investigation) due to their lack of connection with the subject matter. 60 documents were classified as n°1 (qualified, water transfer mentioned in title) and 128 documents were classified as n°2 (qualified, water transfer mentioned in abstract). According to the results, 82.7 % of the total documents were eliminated because many documents were included in the first search (related to water transfer), but with the general theme of integrated water resources management (IWRM). The abstract criterion's results discarded a total of 120 documents, leaving 8 selected for the content study. Finally, 80 documents were obtained that passed the eligibility criteria made in the SLR. An additional 12 were deleted at the full-text reading stage due to language and deviation from the subject matter in the body of the report. Through this filtering process, a total of 68 documents were analyzed in the content analysis and the quality information assessment (see Table S2 of the supplementary material). In general, the low number of documents selected allowed us to concentrate on those case studies that, beyond studying the IBTs, consider sustainability as one of the central themes within the research.

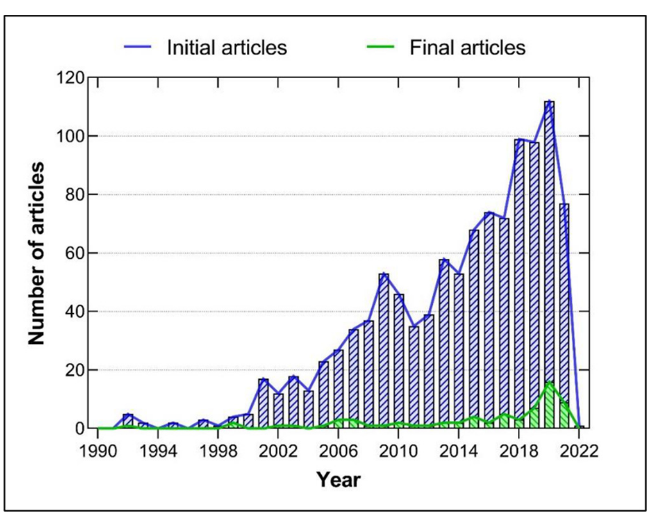

Fig. 5. Distribution by year of the documents without duplicates obtained from the search equation (blue, n total = 1088) and the documents selected for the evaluation of the informative quality and the content analysis (green, n total = 68).

3.2. Assessment of document quality and relevance

The results of this analysis are presented graphically in Fig. 6 (the evaluation of the 68 documents based on the five aforementioned evaluation questions (Section 2.3) are presented in the supplementary material: Table S4. Questions 1 and 2, concerning the social and economic perspective of the studies, showed the lowest number of highly informative documents with a total percentage of 60.3 % and 52.9 %, respectively. Question 3, corresponding to the environmental pillar of sustainability, revealed the most significant number of highly informative documents with 88.2 %, indicating that the environmental pillar was a focal point for studying the impact of IBT projects. Question 4, which evaluated the quantitative nature of the study, obtained a total of 64.7 % for highly informative, showing that more than half of the selected documents had a quantitative justification for the evidence of project impact. Question 5 evaluates the size of the case study for each document, following the criteria proposed by Shumilova et al. (2018), classifying them as water transfer projects and megaprojects, where 67.7 % of the selected documents contained at least one megaproject in the case/s study. In general, a very low proportion of documents were considered "unclear" in any of the five evaluated aspects of information quality. There was a 1.5 % lack of clarity in questions from 1 to 4, and 14.7 % in Question 5. This is because, in some documents, little information was provided regarding the characteristics of the IBTs studied. Overall, we see that the sample taken is representative to extract evidence regarding the impacts generated by IBTs worldwide, having >50 % of highly informative character in each of the five questions posed, obtaining an overall average of 66.8 % for highly informative.

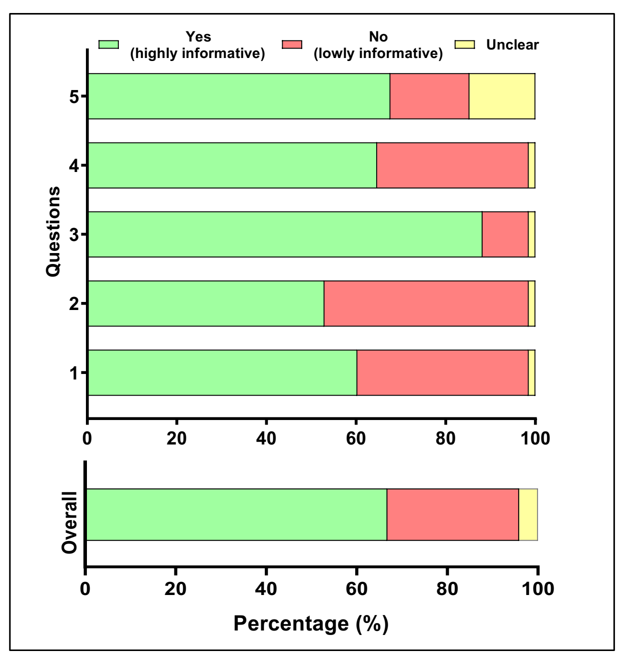

Fig. 6. General evaluation of the informative quality of the model based on the risk assessment of bias in meta-analyses and systematic type reviews (Hoy et al., 2012; Petermann-Rocha et al., 2022; Xia et al., 2021; Zare Sakhvidi et al., 2022). The questions were: (1) Does the study take a social perspective on sustainability? (2) Does the study take an economic perspective on sustainability? (3) Does the study take an environmental perspective on sustainability? (4) Is it a quantitative study? (5) Is at least one of the study cases in the document considered a transfer megaproject?

3.3. Content analysis

A total of 107 extracts distributed in 41 codes (13 positive impact categories and 28 negative impact categories, see detailed results in Table 1) emerged from the coding analysis of the documents. We sought to keep the designation of positive or negative sustainability impacts within the 68 documents as objective as possible by explicitly considering impacts stated by the document's authors. These analyses revealed 36 extracts referring to positive and 71 to negative impacts. Table 2 presents the distribution of positive and negative codes presented as a total count and percentage of coded extracts.

The impacts associated with the unsustainability of an IBTs were more frequently presented in the documents selected by the systematic review, obtaining approximately double the negative impacts related to the three pillars of sustainability. Results show that the success of an IBT is mainly tied to the economic pillar of sustainability, surpassing the extracts that enhance the failure, evidencing the high efficiency of these projects to promote the economic development of the country or the region (Fig. 7). However, it also shows the low effectiveness and commitment to sustainable development in terms of social and environmental dimensions, obtaining a high difference between the positive and negative extracts of these two (Fig. 7).

Table 1
Codes obtained from the content evaluation carried out on the 68 selected articles (n_codes = 41, n_extracts = 107). Impacts must be explicitly and directly associated with an IBT project.

		EXTRACTS
1.	SUCCESS IMPACTS	EXTRACTS
1.1.	Environmental (success)	16
1.1.1	Benefits to the natural ecosystem	5
1.1.2	Benefits of hydrological connectivity	2
1.1.3	Benefits of flow control	1
1.1.4	Dilution in water quality deterioration	1
1.1.5	Mitigation of river drought	3
1.1.6	Mitigate groundwater overturn	3
1.1.7	Mitigate water scarcity in critical basins	1
1.2.	Economy (success)	11
1.2.1	Economic benefits level Country	6
1.2.2	Allow economic development based on profits	4
1.2.3	Transfer cheaper than desalination	1
1.3.	Social (success)	9
1.3.1	Benefits in agriculture	3
1.3.2	Good compensation for impacts	1
1.3.3	Guarantee of water supply	5
2.	FAILURE IMPACTS	EXTRACTS
2.1.	Environmental (failure)	35
2.1.1	Increased evapotranspiration in the receiving basin	1
2.1.2	Water level rise in receiving areas	2
2.1.3	Changes in the natural cycle of river basins	3
2.1.4	Changes in the nature of rivers	5
2.1.5	Contamination of transbasin water	7
2.1.6	Landslides and Effects in Channels	3
2.1.7	greenhouse gas emissions	1
2.1.8	Lack of environmental impact assessment	1
2.1.9	Impacts on the marine ecosystem	6
2.1.10	Saltwater intrusion during transfer	2
2.1.11	soil salinization	3
2.1.12	Overfishing of aquaculture vessels	1
2.2.	Economia (failure)	8
2.2.1	Damage to development capacity due to loss of Ecosystem service value (ESV)	1
2.2.2	Demand provided below the supply	1
2.2.3	No consideration of cost-benefit uncertainty in previous studies	1
2.2.4	problems with project quality and cost overruns	4
2.2.5	Cost overrun for land acquisition	1
2.3.	Social (failure)	28
2.3.1	High price of transbasin water	7
2.3.2	Problems with compensatory measures for the affected population	3
2.3.3	damage to the tourist environment	1
2.3.4	Impact on ethnic groups	1
2.3.5	Impacts in rural areas	2
2.3.6	Unequal participation of stakeholders	1
2.3.7	loss of water for locals	2
2.3.8	losses of fertile fields in agriculture	1
2.3.9	Affected population as indirect beneficiaries	2
2.3.10	Problems to the archaeological heritage	1
2.3.11	Relocation of the affected population	7

Table 2
Results of the codebook in the content analysis (n total = 107 extracts).

	# of Codes			Percentage %		
Pillar of Sustainability	Positive	Negative	Variation[1]	Positive	Negative	Variation[2]
Environmental	16	35	- 19	14.9	32.7	-54%
Economic	11	8	+ 3	10.3	7.5	38%
Social	9	28	- 19	8.4	26.2	-68%
Total	36	71	- 35	33.6	66.4	-49%

[1]Variation calculated as (positive – negative).
[2]Percentage variation calculated as [(positive – negative)/negative] × 100.

Interestingly, our analyses reveal 50 % more negative impacts than positive impacts resulting from IBT projects, which translates to one positive impact for every two negative impacts. This points to the immense challenge of achieving sustainability with IBT projects. We see that these associated negative impacts are mostly related to the social and environmental pillars of sustainability. Fig. 8 provides more details on the nature of the positive and negative impacts of IBTs from our analysis. It shows the top-ten positive impacts with the highest mention within the selected documents (33 of the 36 positive impact excerpts found, represented by green horizontal bars), along with the top-ten negative impact codes with the highest mention within the selected documents (48 of the 71 negative impact excerpts found, represented by horizontal red bars).

Positive impacts mainly fell within the environmental sustainability pillar (14.9 %, Fig. 7), representing the benefits of water transfer for both the basin and the receiving agents. Examples of positive impacts included the hydrological connectivity between basins that mitigates the problem of heterogeneous distribution of water resources across previously isolated lakes (Guo et al., 2020; Xu et al., 2018), the benefit of flow control, which can avoid degrading the water quality in the rivers under low flow conditions (Liu et al., 2021)and the general drought mitigation (Jiang et al., 2020; Qingtao et al., 1999; Soulsby et al., 1999). Positive impacts also included the mitigation of groundwater overexploitation due to groundwater stress dependence in the area (He et al., 2010; Rogers et al., 2020; Xu et al., 2018) as well as benefits to natural ecosystems from improving multiple wetlands, rehabilitation of natural vegetation, and restoration of damaged ecosystems (Ding et al., 2020; He et al., 2010; Lu et al., 2006; Yu et al., 2018) (see detailed results in Table 1). However, the most frequently cited positive impact overall was the resultant economic benefit from

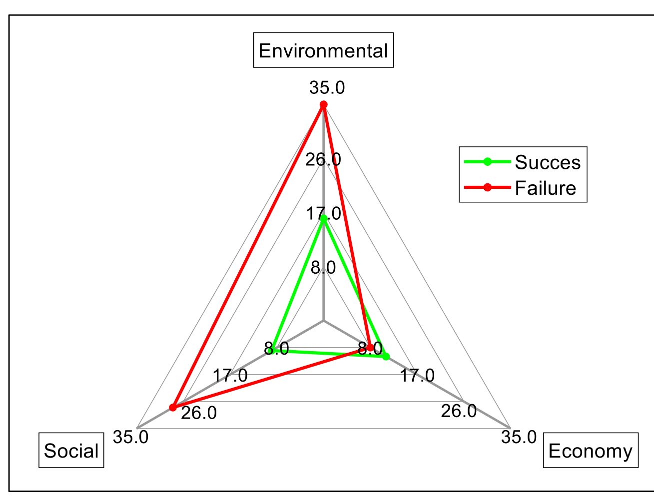

Fig. 7. Radial diagram showing the total number of impacts per sustainability pillar. Total positive impacts were 36. Total negative impacts were 71. Total impacts n = 107.

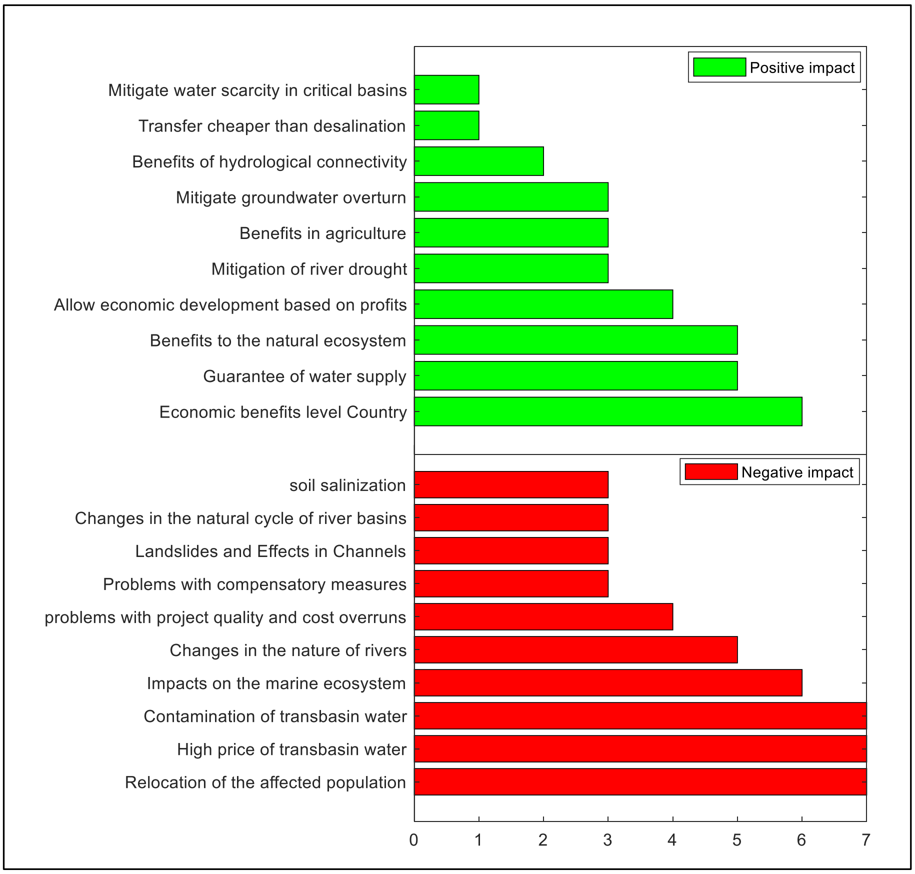

Fig. 8. Stacked bar graph of the 10 codes that most found references in the literature for positive and negative impacts. The horizontal axis corresponds to the number of references.

IBTs at the country level, increasing the gross domestic product (GDP) of countries such as China, USA, or Spain, countries where these megaprojects are mostly developed. For example, the SNWTP in China stimulated economic development which allowed the country to maintain the economic growth rate of 8.5 % and generated in increase in the country's GDP of more than $75 billion per year by 2020 (Feng et al., 2007). In contrast, the extracts referring to the social benefits of the project (8.4 %, Fig. 7) were the least mentioned, showing that despite being initiatives aimed at redistributing a resource that would directly benefit society, economic and environmental impacts are more frequently the metric cited for project sustainability. Conversely, the highest number of references to negative impacts related mostly on the environmental pillar (32.7 %) and social pillar (26.2 %. including problems with relocation policies of the affected population (He et al., 2010; Purvis and Dinar, 2020; Wang et al., 2021; Zhao et al., 2017), the high price of transferred water (Laurenceau et al., 2020; Luo and Webber, 2020; Sheng et al., 2020; Wang et al., 2012; Yu et al., 2018), pollution during water transfer (Cheng and Song, 2009; Hao et al., 2018; Liu et al., 2021; Wilson et al., 2017), and the impact on the marine ecosystem and biodiversity (Ding et al., 2020; Divya et al., 2021; Guo et al., 2020; Laurenceau et al., 2020; Purvis and Dinar, 2020; Yu et al., 2018) (see detailed results in Table 1). These results indicate that the main impacts of IBT unsustainability are not as strongly cited as or related to the economy. This is consistent with the finding that the most cited positive impact relates to economic benefits at the country level.

3.3.1. Spatial distribution of evidence

The 107 coded excerpts on IBT project sustainability impacts referred to 23 projects distributed in 16 countries around the world (Table 3). China provided 62.6 % of the total coded excerpts on sustainability impacts ($n = 67$), mainly due to the international importance of the South-North Water Transfer Project (SNWTP), due to its size, scope, and potential for both positive and negative social, environmental, and economic impacts.

In the case of coded impacts from Bangladesh, IBTs were identified without further specification, so the name and characteristics of the project were not obtainable. The codes from Australia referred to an irrigation area fed by a transfer project, but the name and characteristics of the project (s) were not specified. The rest of the 104 coded impacts were associated with a project that had identifiable characteristics within the document or its references. They were considered as the main features of each project:

Table 3
Summary of positive and negative case study extracts by country.

Country	# of codes		Overall	
	Positive	Negative	Cumulative	Percentage %
Australia	1	0	1	0.93
Bangladesh	0	2	2	1.87
Bolivia	0	1	1	0.93
Brazil	0	2	2	1.87
China	23	44	67	62.62
England	2	0	2	1.87
France	0	3	3	2.80
Iran	0	2	2	1.87
Japan	0	1	1	0.93
Libya	1	0	1	0.93
Nepal	0	3	3	2.80
South Africa	6	3	9	8.41
Spain	3	5	8	7.48
Thailand	0	1	1	0.93
USA	0	3	3	2.80
Yemen	0	1	1	0.93
Total	36	71	107	100 %

current status; project objective; transfer distance [km], transported flow [km3/year] and estimated cost [trillion US$] (details of the projects and their characteristics can be found in Table S3 of the supplementary material). The data for each project were mainly extracted from the document mentioning the coded impact and/or references to it. In addition, the data published together with the article by Shumilova et al. (2018) were used to complete the missing information. Overall, the most representative project in the literature was the SNWTP, which generated numerous positive impacts including improved hydrological connectivity, mitigation of groundwater overturn, economic benefits, and guarantee of consistent water supply. On the other hand, many negative impacts from the SNWTP stand out in the literature, including the contamination of transbasin water, deleterious impacts on the marine ecosystem, and damage to development capacity due to a decline in ecosystem service value (ESV) and a high price of transbasin water (Fig. 8).

Overall, the spatial distribution of the coded impacts is mainly concentrated in the Asian continent (77 extracts) due mainly to the high level of investigation on the SNWTP (67 of the 77 extracts). As was seen for the other projects, the SNWTP had twice as many negative impacts compared to positive impacts. We visually present the spatial distribution of IBT projects in Fig. 9. In the Americas, there were 6 coded impacts in total (only above Australia) distributed between Bolivia, Brazil, and the United States, where it is noted that all were negative impacts. No coded impacts were found from countries with regionally relevant economies such as Chile, Mexico or Canada. In Africa, Europe and Australia, 10 (7 positive and 3 negative), 13 (5 positive and 8 negative) and 1 (positive) impact were identified, respectively (Fig. 9).

Overall, we see that the distribution of referenced IBT project impacts is uneven across the world, concentrating mainly on China. Only negative impacts are concentrated in the Americas, distributed in three of the 57 countries that make up the continent. This indicates that not many projects are documented in the literature and that there is little to no characterization of these projects in terms of sustainability. Of the six negative impacts identified in the Americas, four correspond to negative effects on the social pillar of sustainability, showing where the main problem of IBTs is concentrated in these study areas. Conversely, in Libya, Australia, and England, only positive environmental and economic impacts were found, although they are within the group that composes the least number of coded impacts obtained with 0.93 % for Australia and Libya, and 1.87 % for England.

3.3.2. Impacts excluding Chinese IBT projects

Because our study revealed a disproportionate number of IBT case studies for China, an analysis without China was performed. Table 4 compares the distribution of impacts across the three sustainability pillars. From a high level, we see a similar trend to what was found previously (i.e., with twice as many codes associated with a negative impact compared to positive impacts). However, we see differences in how the nature and frequency of impacts differ with respect to the three pillars. For example, the most significant number of codes associated with positive impacts (when excluding China from the analysis) centered on the economic pillar, leaving the environmental pillar as the least mentioned. This shows the significant contribution of environmental benefits obtained from the projects carried out in China (mainly the SNWTP, having a greater transport capacity, distance

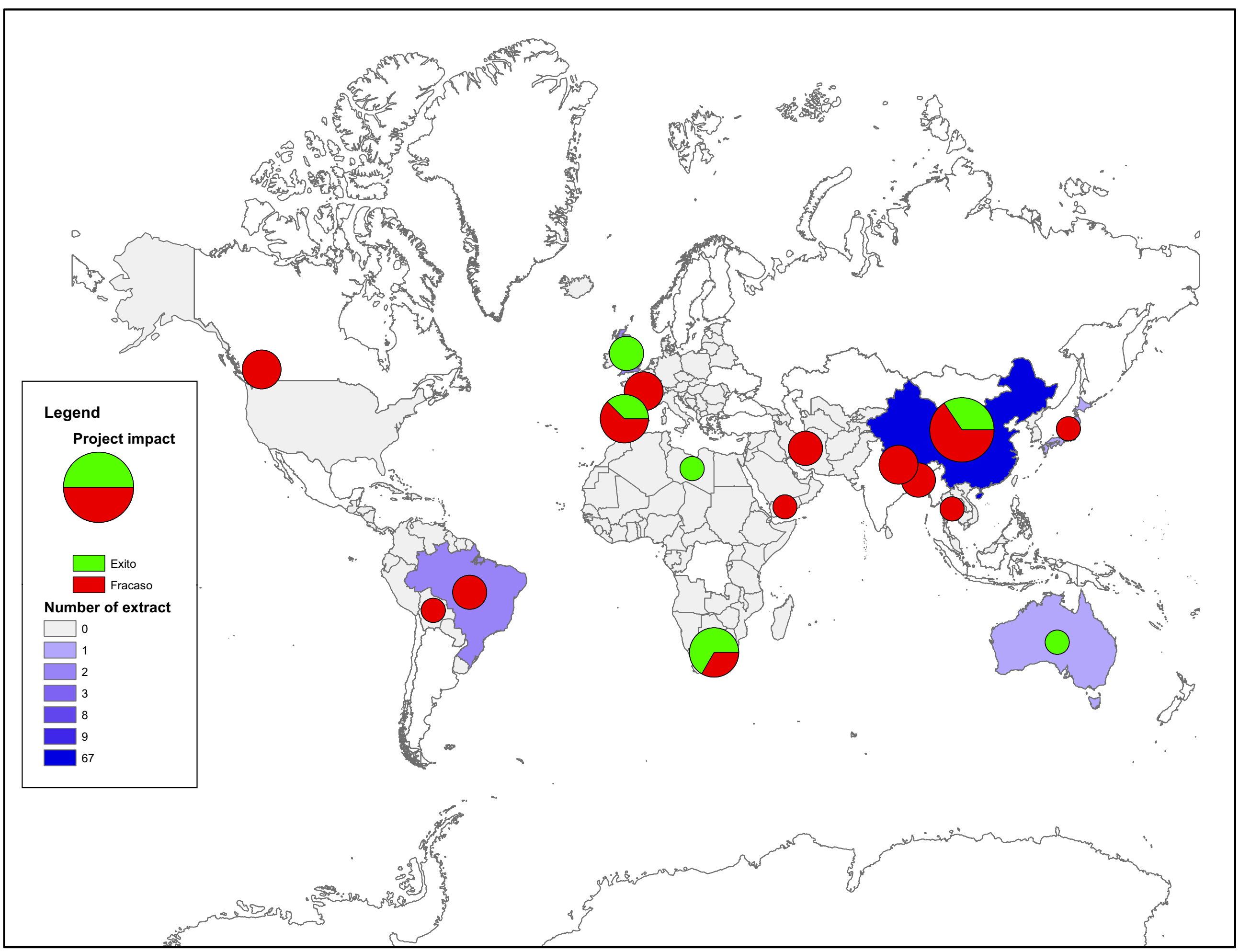

Fig. 9. Spatial distribution map of the extracts by country, indicating the number of coded impacts (heat map with a scale from 0 to 67) and the distribution of positive and negative impacts by country (circular graph representing positive impacts in green and negative impacts in red).

Table 4
Comparison of results obtained for total extracts vs extracts without considering China's project.

	Analysis 1: Total of coded impacts (n = 107)			Analysis 2: Codes excluding Chineseprojects (n = 40)			Variation between the analyses [%]	
Pillar of Sustainability	Positive	Negative	Variation[1] %	Positive	Failure	Variation[1] %	Positive[2]	Negative[2]
Environmental	16	35	-54%	2	10	-80%	-88%	-71%
Economy	11	8	38%	7	2	250%	-36%	-75%
Social	9	28	-68%	4	15	-73%	-56%	-46%
Total	36	71	-49%	13	27	-52%	-64%	-62%

[1] Variation calculated as (positive – negative).
[2] Percentage variation calculated as [(positive – negative)/negative].

cost, and impacting a greater number of sectors and beneficiaries). For the economic pillar, the gap between the codes associated with positive impacts increased, resulting in 2.5 times more positive impacts referenced than negative impacts (see Table 4). Finally, the social dimension has the most cited negative impacts (n = 15, when excluding Chinese projects), indicating that, more broadly, negative social impacts are the most detrimental to overall IBT project sustainability. The most frequently mentioned negative impacts include the high price of transferred water, insufficient compensatory measures, impacts on rural areas (e.g., erosion of the local tax base, degradation of the formerly irrigated land, and threats to the economic health and lifestyle of rural areas), and displacement and relocation of the local population.

4. Discussion

The study results reveal a lack of research characterizing the positive and negative impacts of IBT projects regarding social, environmental, and economic sustainability. Out of a total of 1088 documents, only 68 were selected under the three eligibility criteria that included only investigations that focused on water transfer projects between basins and sustainability or sustainability as a topic of focus. In addition, these studies only included IBTs that were already implemented – excluding those projects that were either not implemented or that are currently under construction. A study of these future projects thus becomes an essential tool for future proposals for water resources management. Below we offer additional observations of the study findings as well as areas for further investigation.

4.1. 4.1. Implications of study findings on the UN Sustainable Development Goals

A key focus of this study was on the positive or negative social, environmental, and economic impacts of IBTs. Characterizing these impacts allows us to thoughtfully map IBT impacts over many SDGs to evaluate how IBT projects are situated within sustainable global development. For example, a connection between IBTs on the SGDs relates first to SDG.6, which promotes safe and affordable drinking water for all by 2030. Transfer projects play a major role in water availability in civilization. However, many of the impacts found in this study directly affect the quality of drinking water supply. Within the code “contamination in the transfer” are 7 extracts that refer to water distribution for the SNTWP, which has the primary objective of distributing drinking water to the cities of northern China. (Cheng and Song, 2009; Ding et al., 2020; Hao et al., 2018; He et al., 2010; Liu et al., 2020; Liu et al., 2021; Wilson et al., 2017; Zhao et al., 2019). SDG.7 promotes cleaner and more efficient energy generation for the entire planet, and IBT projects are used for hydropower generation, such as the Orange River Development Project and the Lesotho Highlands Project (LHWP) located in South Africa (Matchaya et al., 2019; Mokorosi and van der Zaag, 2007; Vazquez and Muneepeerakul, 2021); or the transfer project of the state of Colorado in the United States (Dilling et al., 2019). However, the amount of water delivered mainly impacts the donor basin, such as hydrological effects on catchment rivers (Tien Bui et al., 2020; Wang et al., 2021; Wilson et al., 2017; Xu et al., 2018). SDG.8, which promotes economic growth and decent work, benefits from transfer megaprojects due to the economic benefits revealed in this study (He et al., 2010; Matchaya et al., 2019; Morote et al., 2017; Qingtao et al., 1999; Vazquez and Muneepeerakul, 2021; Xu et al., 2018; Yu et al., 2018). SDG.14 aims to manage and protect marine and coastal ecosystems, which are adversely affected by some cases of IBTs that cause the migration of species by decreasing their population levels in the donor basin, introducing them into non-native habitats (Ding et al., 2020; Divya et al., 2021; Guo et al., 2020; Laurenceau et al., 2020; Purvis and Dinar, 2020; Yu et al., 2018). Finally, SDG.15 refers to the loss of natural habitat and biodiversity, which may be affected by IBT projects from things such as greenhouse gas emissions from increased energy consumption (Yu et al., 2018); soil salinization; losses of fertile fields for agriculture resulting from the construction of hydraulic infrastructure; and, the mismanagement of land acquisition (Ding et al., 2020; He et al., 2010; Morote et al., 2017; Wilson et al., 2017; Zhao et al., 2017). Overall, IBTs affect at least five SDGs directly, while there is conceivably an indirect impact across all seventeen goals. Therefore, future studies of IBTs impacts are vital for sustainable global development.

4.2. Impact classification and sustainability of IBTs

Within the scope of this research study, all impacts were considered without further classifying their impact across the different states of project design, implementation, and post-implementation. Indeed, it may be assumed that different positive and negative impacts from IBTs would exist before or after the realization of the project, such as the acquisition of land, as opposed to the impacts on the marine ecosystem or the decrease in the water level of the catchment rivers (impacts after the implementation of the project). The effects of the different stages of implementation, operation, and maintenance of an IBTs correspond to impacts that may have positive or negative attributions and that usually manifest after the execution of the project (i.e., during its operation and maintenance). However, there are impacts that affect the design phase before it is executed. These potential impacts can also be identified and considered within the design of IBTs. For example, this study showed negative impacts such as problems in project implementation management, land acquisition, compensation, and relocation of the affected population. The latter implies a need to identify and characterize the different negative impacts that result at different stages of IBT project development to avoid these impacts before proceeding on. Additionally, not all impacts may be considered equal; many may have negligible impacts, while others may have severe and permanent impacts on the project's sustainability and the state of the surrounding environment. Within the context of IBTs, conceivably, the impacts that can cause permanent effects on the various aspects that promote sustainability are potentially most important, as was the case of the Aral Sea, which is considered one of the largest humanitarian disasters in the world where a transfer project in 50 years completely drained a sea of 67,500 km^2 (Zhuang, 2016).

This brings us back to a key finding from this study: the number of negative impacts appears to be twice that of positive impacts generated by an IBT project. While implementation of IBTs has an objective that is usually related to covering a need or solving a problem associated with the use of water in humans or the environment, we see from this study that the cost of meeting this need is potentially high due to the significant number of negative effects that can end up worsening the situation in the long-term.

For example, the impacts identified in the American continent were entirely concentrated on negative effects. Consequently, four of the six negative impacts identified are within the social dimension of sustainability. The latter shows that the cultural and hydro-social factors of American IBTs – and their perception by the population and stakeholders – is very different from how they are considered and assessed in Asian and European countries (e.g., one negative social impact can be considered positive in other parts of the world). Therefore, the characterization of impact relevance and severity throughout the project timeline is the logical next step of future research that focuses on the sustainability of IBTs and their impacts on the environment and society. Of particular interest would be to have longitudinal and quantitative studies that seek to identify the factors that impact IBT project sustainability to further characterize sustainability drivers and the nuanced impacts that result. Future studies are needed to inform and promote IBTs that maximize sustained positive impacts on the environment, society, and economy.

4.3. Study limitations

There are important limitations to highlight that result from this study's inherently complex, multidimensional, and qualitative nature. First, the literature search only included documents from January 1990 to November 2021. More recent studies (those in 2022) on the subject were not included. While these studies could enrich the results obtained by supplementing the information collected, the analysis of the information quality shows that a representative sample was taken for content analysis, and the addition of recent documents does not necessarily imply a drastic change in the results. Second, the restriction of English and Spanish language documents excluded 9 investigations in the Chinese language that could have impacted the study results. In addition, the search equation may have excluded documents that implicitly referenced aspects of IBT sustainability by not explicitly reference the term 'sustainability' in the title, abstract or keywords. Third, sustainability impacts were coded according to the most direct effect produced within the three pillars of sustainability. However, we note that there are instances where impacts could be classified across more than one sustainability pillar and that considering this overlap may have changed our results. Finally, the coding process was conducted by two independent authors (MF and MS). While a check for coding overlap was done in the initial stages of analysis, inconsistencies can impact the study findings. However, our team sought to mitigate these inconsistencies by developing a multi-step document and code review criteria outlined in the methods section.

5. Conclusions

Inequitable distribution of water resources, climate-induced water scarcity, combined with an increasing demand for water, has led countries to seek solutions focused on meeting future water needs. IBT projects offer a potential solution for redistributing water resources. However, these projects involve many significantly adverse impacts, which point to a vital need to apply lessons learned from past projects for decision-making with future projects.

In this study, we applied a systematic literature review methodology and evidence extraction to characterize the multidimensional impacts identified in case studies related to IBT sustainability. Through our analyses, we found that the literature cites twice the number of negative impacts compared to positive impacts from IBTs. Our findings show that majority of positive impacts related to the environmental pillar of sustainability, while the negative impacts related more to the social aspects of sustainability. Through the categorization and classification of impacts, we can also show a salient connection between the positive and negative impacts of IBTs on at least five of the UN SDGs. At the same time, our study points to a disproportionately negative sustainability impact from IBTs. We hope that this study helps direct future research and practice focused on the sustainable implementation of future IBTs. This necessarily requires the continued growth of knowledge regarding best practices and pitfalls for the design, execution, and maintenance of IBTs. Overall, this study provides a first step in these efforts by characterizing the positive and negative impacts of IBTs, allowing future researchers to concentrate efforts on ways to make IBTs more effective and sustainable.

Supplementary data to this article can be found online at https://doi.org/10.1016/j.scitotenv.2022.160500.

CRediT authorship contribution statement

Conceptualization, M.F., H.A., and J.W.; document collection, M.F., H.A., J.W.; systematic review & analysis, M.F., H.A., J.W., A.P., M.S.; writing—original draft preparation, M.F., H.A., A.P.; writing—review and editing, M.F., H.A., J.W., A.P. and M.S.; conceptualization graphical abstract, M.F., H.A., A.P. and M.S.; graphical abstract design, M.S. All authors have read and agreed to the published version of the manuscript.

Data availability

Data used is available at the "Suplementary Material" section

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Alberti, M.A., Blanco, I., Vox, G., Scarascia-Mugnozza, G., Schettini, E., Pimentel da Silva, L., 2022. The challenge of urban food production and sustainable water use: current situation and future perspectives of the urban agriculture in Brazil and Italy. Sustain. Cities Soc. 83, 103961. https://doi.org/10.1016/j.scs.2022.103961.

Bastida-Molina, P., Hurtado-Pérez, E., Moros Gómez, M.C., Cárcel-Carrasco, J., Pérez-Navarro, Á., 2022. Energy sustainability evolution in the Mediterranean countries and synergies from a global energy scenario for the area. Energy 252, 124067. https://doi.org/10.1016/j.energy.2022.124067.

Bonnedahl, K.J., Heikkurinen, P., Paavola, J., 2022. Strongly sustainable development goals: overcoming distances constraining responsible action. Environ. Sci. Pol. 129, 150–158. https://doi.org/10.1016/j.envsci.2022.01.004.

Brundtland, G.H., 1987. Report of the World Commission on Environment and Development:" Our Common Future.". UN.

Cheng, S., Song, H., 2009. Conservation buffer systems for water quality security in south to north water transfer project in China: an approach review. Front. For. China 4 (4), 394–401. https://doi.org/10.1007/s11461-009-0070-y.

Cheng, Z., 2006. The Central Arizona Project: South-to-North Water Transfers and Water Science & Technology.

Dedoose Version 9.0.46, 2021. Web Application for Managing, Analyzing, and Presenting Qualitative and Mixed Method Research Data. SocioCultural Research Consultants, LLC www.dedoose.com, Los Angeles, CA.

Dilling, L., Berggren, J., Henderson, J., Kenney, D., 2019. Savior of rural landscapes or Solomon's choice? Colorado's experiment with alternative transfer methods for water (ATMs). Water Security 6, 100027. https://doi.org/10.1016/j.wasec.2019.100027.

Ding, W., Liu, H., Li, Y., Shang, H., Zhang, C., Fu, G., 2020. Unraveling the effects of long-distance water transfer for ecological recharge. J. Water Resour. Plan. Manag. 146 (9), 02520004. https://doi.org/10.1061/(ASCE)WR.1943-5452.0001272.

Divya, K.R., Zhao, S., Chen, Y., Cheng, F., Zhang, L., Qin, J., Arunjith, T.S., Schmidt, V.B., Xie, S., 2021. A comparison of zooplankton assemblages in Nansi Lake and Hongze Lake, potential influences of the East Route of the South-to-North Water Transfer Project, China. J. Oceanol. Limnol. 39 (2), 623–636. https://doi.org/10.1007/s00343-020-9288-1.

Feng, S., Li, L.X., Duan, Z.G., Zhang, J.L., 2007. Assessing the impacts of south-to-north water transfer project with decision support systems. Decis. Support. Syst. 42 (4), 1989–2003. https://doi.org/10.1016/j.dss.2004.11.004.

Ghassemi, F., White, I., 2007. Inter-Basin Water Transfer: Case Studies from Australia, United States, Canada, China and India.

Grafton, R.Q., Wyrwoll, P., White, C., Allendes, D., 2014. Global water: issues and insights. ANU Press. https://books.google.cl/books?id=KMgZBAAAQBAJ.

Guo, C., Chen, Y., Gozlan, R.E., Liu, H., Lu, Y., Qu, X., Xia, W., Xiong, F., Xie, S., Wang, L., 2020. Patterns of fish communities and water quality in impounded lakes of China's south-to-north water diversion project. Sci. Total Environ. 713, 136515. https://doi.org/10.1016/j.scitotenv.2020.136515.

Hanemann, W.M., 2002. The Central Arizona Project. https://escholarship.org/uc/item/87k436cf.

Hao, R., Zhang, J., Wang, P., Hu, R., Song, Y., Wu, Y., Qiu, G., 2018. Effects of human management on black carbon sorption/desorption during a water transfer project: recognizing impacts and identifying mitigation possibilities. J. Environ. Manag. 214, 346–353. https://doi.org/10.1016/j.jenvman.2018.02.081.

He, C., He, X., Fu, L., 2010. China's south-to-north water transfer project: is it Needed?: China's south-to-north water transfer project. Geogr. Compass 4 (9), 1312–1323. https://doi.org/10.1111/j.1749-8198.2010.00375.x.

Hoy, D., Brooks, P., Woolf, A., Blyth, F., March, L., Bain, C., Baker, P., Smith, E., Buchbinder, R., 2012. Assessing risk of bias in prevalence studies: modification of an existing tool and evidence of interrater agreement. J. Clin. Epidemiol. 65 (9), 934–939. https://doi.org/10.1016/j.jclinepi.2011.11.014.

Issaoui, M., Jellali, S., Zorpas, A.A., Dutournie, P., 2022. Membrane technology for sustainable water resources management: challenges and future projections. Sustain. Chem. Pharm. 25, 100590. https://doi.org/10.1016/j.scp.2021.100590.

Jiang, W., Pan, B., Chen, J., Jiang, X., Shen, H., Zhu, T., 2020. Macroinvertebrate communities in a Lake of an Inter-Basin water transfer project and its implications for sustainable management. Water 12 (7), 1900. https://doi.org/10.3390/w12071900.

Kumar, R.R., Pandey, A.K., Samykano, M., Aljafari, B., Ma, Z., Bhattacharyya, S., Goel, V., Ali, I., Kothari, R., Tyagi, V.V., 2022. Phase change materials integrated solar desalination system: an innovative approach for sustainable and clean water production and storage. Renew. Sustain. Energy Rev. 165, 112611. https://doi.org/10.1016/j.rser.2022.112611.

Laurenceau, M., Molle, F., Grau, M., 2020. Reducing water withdrawals: the negotiation and implementation of environmental policy in the Durance River Basin, France. Water Policy 22 (6), 1217–1236. https://doi.org/10.2166/wp.2020.112.

Liu, J., Li, M., Wu, M., Luan, X., Wang, W., Yu, Z., 2020. Influences of the south–to-north water diversion project and virtual water flows on regional water resources considering both water quantity and quality. J. Clean. Prod. 244, 118920. https://doi.org/10.1016/j.jclepro.2019.118920.

Liu, W., Kuo, Y.-M., Zhao, E., 2021. Influence of the south-to-north water transfer and the Yangtze River mitigation projects on the water quality of Han River, China. Environ. Earth Sci. 80 (7), 246. https://doi.org/10.1007/s12665-021-09534-5.

Lu, Z., Ma, X., Sang, W., Fan, Y., 2006. Ecological benefit assessment of the south-north water transfer project: an eastern route. Int J Sust Dev World 13 (3), 221–227. https://doi.org/10.1080/13504500609469674.

Luo, Z., Webber, M., 2020. Between Project and Region: The Challenges of Managing Water in Shandong Province After the South-North Water Transfer Project. 13(1), p. 22.

Manju, S., Sagar, N., 2017. Renewable energy integrated desalination: a sustainable solution to overcome future fresh-water scarcity in India. Renew. Sust. Energ. Rev. 73, 594–609. https://doi.org/10.1016/j.rser.2017.01.164.

Matchaya, G., Nhamo, L., Nhlengethwa, S., Nhemachena, C., 2019. An overview of water Markets in Southern Africa: an option for water Management in Times of scarcity. Water 11 (5), 1006. https://doi.org/10.3390/w11051006.

Meador, M.R., 1992. Inter-basin water transfer: ecological concerns. Fisheries 17 (2), 17–22. https://doi.org/10.1577/1548-8446(1992)017<0017:IWTEC>2.0.CO;2.

Meerganz von Medeazza, G., 2004. Water desalination as a long-term sustainable solution to alleviate global freshwater scarcity? A North-South approach. Desalination 169 (3), 287–301. https://doi.org/10.1016/j.desa1.2004.04.001.

Mokorosi, P.S., van der Zaag, P., 2007. Can local people also gain from benefit sharing in water resources development? Experiences from dam development in the Orange-Senqu River Basin. Phys. Chem. Earth A/B/C 32 (15–18), 1322–1329. https://doi.org/10.1016/j.pce.2007.07.028.

Morote, Á.-F., Olcina, J., Rico, A.-M., 2017. Challenges and proposals for socio-ecological sustainability of the tagus-Segura aqueduct (Spain) under climate change. Sustainability 9 (11), 2058. https://doi.org/10.3390/su9112058.

Page, M.J., McKenzie, J.E., Bossuyt, P.M., Boutron, I., Hoffmann, T.C., Mulrow, C.D., Shamseer, L., Tetzlaff, J.M., Akl, E.A., Brennan, S.E., Chou, R., Glanville, J., Grimshaw, J.M., Hróbjartsson, A., Lalu, M.M., Li, T., Loder, E.W., Mayo-Wilson, E., McDonald, S., McGuinness, L.A., Stewart, L.A., Thomas, J., Tricco, A.C., Welch, V.A., Whiting, P., Moher, D., 2021. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ, n71 https://doi.org/10.1136/bmj.n71.

Pereira, L., Cordery, I., Iacovides, I., 2009. Coping with Water Scarcity. Coping with Water Scarcity by Luis Santos Pereira, Ian Cordery, and Iacovos Iacovides. 2009. Springer, Berlin. https://doi.org/10.1007/978-1-4020-9579-5_1 ISBN: 978-1-4020-9578-8.

Petermann-Rocha, F., Balntzi, V., Gray, S.R., Lara, J., Ho, F.K., Pell, J.P., Celis-Morales, C., 2022. Global prevalence of sarcopenia and severe sarcopenia: a systematic review and meta-analysis. J. Cachexia. Sarcopenia Muscle 13 (1), 86–99. https://doi.org/10.1002/jcsm.12783.

Purvis, L., Dinar, A., 2020. Are intra- and inter-basin water transfers a sustainable policy intervention for addressing water scarcity? Water Security 9, 100058. https://doi.org/10.1016/j.wasec.2019.100058.

Qingtao, X., Xinan, G., Ludwig, H.F., 1999. The wanjiazhai water transfer project, China: an environmentally integrated water transfer system. Environmentalist 19 (1), 39–60. https://doi.org/10.1023/A:1006541023910.

de Queiroz, A.R.S., Motta-Veiga, M., 2012. Análise dos impactos sociais e à saúde de grandes empreendimentos hidrelétricos: Lições Para uma gestão energética sustentável. Cien. Saude Colet. 17 (6), 1387–1398. https://doi.org/10.1590/S1413-81232012000600002.

Rogers, S., Chen, D., Jiang, H., Rutherfurd, I., Wang, M., Webber, M., Crow-Miller, B., Barnett, J., Finlayson, B., Jiang, M., Shi, C., Zhang, W., 2020. An integrated assessment of China's South—North water transfer project. Geogr. Res. 58 (1), 49–63. https://doi.org/10.1111/1745-5871.12361.

Sarkodie, S.A., 2022. Winners and losers of energy sustainability—global assessment of the sustainable development goals. Sci. Total Environ. 831, 154945. https://doi.org/10.1016/j.scitotenv.2022.154945.

Sheng, J., Tang, W., Webber, M., 2020. Can interbasin water transfer affect water consumption and pollution? Lessons from China's south-north water transfer project. Environ. Policy Gov. 30 (6), 345–358. https://doi.org/10.1002/eet.1891.

Shumilova, O., Tockner, K., Thieme, M., Koska, A., Zarfl, C., 2018. Global water transfer megaprojects: a potential solution for the water-food-energy nexus? Front. Environ. Sci., 6.. https://www.frontiersin.org/article/10.3389/fenvs.2018.00150.

Soulsby, C., Gibbons, C.N., Robins, T., 1999. Inter-Basin water transfers and drought management in the Kielder/Derwent system. Water Environ. J. 13 (3), 213–223. https://doi.org/10.1111/j.1747-6593.1999.tb01037.x.

Tan, N.P.B., Ucab, P.M.L., Dadol, G.C., Jabile, L.M., Talili, I.N., Cabaraban, M.T.I., 2022. A review of desalination technologies and its impact in the Philippines. Desalination 534, 115805. https://doi.org/10.1016/j.desal.2022.115805.

Tien Bui, D., Talebpour Asl, D., Ghanavati, E., Al-Ansari, N., Khezri, S., Chapi, K., Amini, A., Thai Pham, B., 2020. Effects of Inter-Basin water transfer on water flow condition of Destination Basin. Sustainability 12 (1), 338. https://doi.org/10.3390/su12010338.

Uhlenbrook, S., Yu, W., Schmitter, P., Smith, D.M., 2022. Optimizing the water we eat—rethinking policy to enhance productive and sustainable use of water in Agri-food systems across scales. Lancet Planet. Health 6 (1), e59–e65. https://doi.org/10.1016/S2542-5196(21)00264-3.

United Nations, 2018. The 2030 Agenda and the Sustainable Development Goals: An opportunity for Latin America and the Caribbean, p. 94.

Vazquez, K., Muneepeerakul, R., 2021. Modeling resilience and sustainability of water-subsidized systems: an example from Northwest Costa Rica. Sustainability 13 (4), 2013. https://doi.org/10.3390/su13042013.

Wang, H., Chen, Z., Ivan Su, S.-I., 2012. Optimalpricing and coordination schemes for the Eastern Route of the South-to-North water diversion supply chain system in China. Transp. J. 51 (4), 487–505. https://doi.org/10.5325/transportationj.51.4.0487.

Wang, Z., Nixon, R., Erwin, A., Ma, Z., 2021. Assessing the impacts of large-scale water transfer projects on communities: lessons learned from a systematic literature review. Soc. Nat. Resour. 34 (6), 822–843. https://doi.org/10.1080/08941920.2020.1859029.

Wilson, M., Li, X.-Y., Ma, Y.-J., Smith, A., Wu, J., 2017. A review of the economic, social, and environmental impacts of China's south-north water transfer project: a sustainability perspective. Sustainability 9 (8), 1489. https://doi.org/10.3390/su9081489.

Xia, X., Chan, K.H., Lam, K.B.H., Qiu, H., Li, Z., Yim, S.H.L., Ho, K.-F., 2021. Effectiveness of indoor air purification intervention in improving cardiovascular health: a systematic review and meta-analysis of randomized controlled trials. Sci. Total Environ. 789, 147882. https://doi.org/10.1016/j.scitotenv.2021.147882.

Xu, X.-Z., Song, G.-D., Dang, T.-M., Liu, J.-W., Zhang, H.-W., Gao, H., Liu, Y.-K., 2018. Environment and sustainability of the middle route, south-to-north water transfer project in China: a close look. Environ. Dev. Sustain. 20 (6), 2415–2426. https://doi.org/10.1007/s10668-017-9996-7.

Yan-Jun, D., 2008. Inspiration of inter-basin water transfer abroad on operation of middle route of South-to-North Water Transfer Project. Adv. Sci. Technol. Water Resour. 28 (2), 79–83.

Yu, M., Wang, C., Liu, Y., Olsson, G., Wang, C., 2018. Sustainability of mega water diversion projects: experience and lessons from China. Sci. Total Environ. 619–620, 721–731. https://doi.org/10.1016/j.scitotenv.2017.11.006.

Zare Sakhvidi, M.J., Knobel, P., Bauwelinck, M., de Keijzer, C., Boll, L.M., Spano, G., Ubalde-Lopez, M., Sanesi, G., Mehrparvar, A.H., Jacquemin, B., Dadvand, P., 2022. Greenspace exposure and children behavior: a systematic review. Sci. Total Environ. 824, 153608. https://doi.org/10.1016/j.scitotenv.2022.153608.

Zhang, L., Li, S., Loáiciga, H.A., Zhuang, Y., Du, Y., 2015. Opportunities and challenges of interbasin water transfers: a literature review with bibliometric analysis. Scientometrics 105 (1), 279–294. https://doi.org/10.1007/s11192-015-1656-9.

Zhao, H., Huang, Y., You, S., Wu, Y., Zheng, F., 2019. A framework for assessing the effects of afforestation and south-to-north water transfer on nitrogen and phosphorus uptake by plants in a critical riparian zone. Sci. Total Environ. 651, 942–952. https://doi.org/10.1016/j.scitotenv.2018.09.226.

Zhao, Z.-Y., Zuo, J., Zillante, G., 2017. Transformation of water resource management: a case study of the south-to-north water diversion project. J. Clean. Prod. 163, 136–145. https://doi.org/10.1016/j.jclepro.2015.08.066.

Zhuang, W., 2016. Eco-environmental impact of inter-basin water transfer projects: a review. Environ. Sci. Pollut. Res. 23 (13), 12867–12879. https://doi.org/10.1007/s11356-016-6854-3.