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Systematic Map Protocol

Title
What is the evidence on the implementation of intersectoral freshwater-wastewater swaps in the world?

Correction (Aug 21, 2026):
The name of one author needs to be corrected. The correct author name should be: Jacqualyn Eales

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Keywords
Future water demand, Priority sector, Urban expansion, Water scarcity, Water reallocation (Freshwater, Intersectoral, Swap, Wastewater).

Background
Water scarcity is rising due to population growth, economic expansion, and climate change (Schewe et al., 2014; Gosling and Arnell, 2016; Liu et al., 2017; Lahham et al., 2022; Eldabbagh and Nicol, 2025). This shortage sparks intense sectoral competition, worsened by increasing pollution (van Vliet et al., 2021). Three main strategies address this gap: reducing demand through efficiency and productivity, generating "new" water (through desalination or wastewater treatment), and realigning resources through reallocation. (Qadir et al., 2007; World Bank 2018; He et al 2021; Ricart et al 2021; Mateo-Sagasta et al., 2022; Velpuri et al 2023). A promising but understudied approach is the Freshwater-Wastewater Swap (FWS). This mechanism involves an intersectoral arrangement in which a freshwater donor sector reallocates part of its freshwater to other sectors or to the environment in exchange for a non-conventional water source as a substitute. This arrangement may be formal (contractual, regulated) or informal (customary, negotiated). Intersectoral FWS can involve any combination of the following six water-use sectors: (1) Agricultural; (2) Municipal/urban; (3) Industrial; (4) Cooling; (5) Recreational; and (6) Environmental. Any sector can act as freshwater donor, alternative water supplier, or freshwater recipient. Although some existed specific cases of FWS have been partially assessed (Danso et al 2018, Drechsel et al 2018, Heinz et al 2011.), there is no global synthesis describing what types, how many and where these exchanges have been implemented and documented. Such information is essential to understand external factors (e.g., policies, institutions, economic incentives, perceptions) and internal factors (e.g., quantity and quality of water exchanged, infrastructure, technologies) that made the FWS possible and effective. This study aims to map global cases of the FWS and extract lessons that can support decisions in countries which intend to promote this approach, such as Jordan (Tawfik et al 2023).

Theory of change or causal model
FWS is defined by three key features: (a) conditionality, linking freshwater release to alternative

water supply; (b) intersectoral exchange involving at least two sectors; and (c) functional substitution, where alternative water enables freshwater reallocation. The freshwater recipient and alternative supplier are separate entities. As in Figure 1a (Appendix 1) agriculture releases freshwater to supply growing city and receives nutrient-rich treated wastewater in return. Another possible case can be seen in the appendix 1 (Figure 1b). Farmers will benefit from nutrient-rich wastewater as alternative to chemical fertilizers and increase their profits while city secures expanded future water demand.

Stakeholder engagement
Stakeholders were strategically engaged through institutional networks to ensure a comprehensive review. Outreach focused on IWMI researchers, supported by experts from partner institutions with strong collaboration records, enabling effective data sharing, alignment with field realities, and expert validation. Engagement was strengthened during Cairo Water Week 2025 through discussions on FWS involving policymakers, utilities, researchers, private sector actors, and development partners. Policymakers, academics, and planners contributed to formulating research questions, while experienced stakeholders supported access to grey literature. External reviewers assisted in screening and defining eligibility criteria. Egyptian water and wastewater experts were actively involved, including through a dedicated workshop to refine research questions. Stakeholders are primarily based in Egypt and Spain, with additional input from experts at UN-Water, World Bank water department, UNESCO, CGIAR, and IWMI through online consultations. Findings will be shared with key stakeholders during a pre-scheduled Cairo workshop under water scarcity initiative to strengthen cross-sector governance.

Objectives and review question
To map and synthesize global evidence on implemented and proposed freshwater-wastewater swaps (FWS), identifying their drivers, policy and regulatory enablers, costs, benefits, sectoral implications, and evidence gap to support water security and sustainability in water-scarce regions. Primary question: What evidence exists on implemented or theoretically proposed intersectoral freshwater-wastewater swaps and their benefits and implications in the world?

Definitions of the question components
Based on the PICO framework, elements of the primary questions are: Population: Anywhere in the world where FWS between two or more sectors is implemented or theoretically explored to resolve water scarcity problem. These regions are highly likely to experience permanent or temporary water scarcity. Intervention: Intersectoral FWS, defined as a formal exchange between users: a "freshwater donor" relinquishes its high-quality water allocation to another user in exchange for treated wastewater. Comparator: If present, regions/areas where there is no intersectoral FWS, or baseline data before intervention. Outcome: If present, any measured or anticipated economic, environmental, and/or social benefits/implications. Study types: 1. Case studies/reports of implemented intersectoral FWS. 2. Empirical research studies reporting effectiveness or outcomes of intersectoral FWS. 3. Theoretical studies of potential intersectoral FWS, reporting hypothesized impact/effectiveness.

Search strategy
A comprehensive search strategy was designed via series of search test and improvement using Scopus database. A search string was designed around the intervention component, either as a phrase, or as components of it (see Table 1a and 1b in Appendix 2) were searched in “title-abstract-keywords" of the Scopus database (Title-Abs-Key). There were no geographical restrictions or date restrictions. Scoping involved testing search terms one by one and recording additional hits and relevance, and testing search operators like *, W/15, and W/25. Selection of search string was based on sensitivity that is measured by numbers of retrieved benchmark articles and specificity which

aims to minimize irrelevant hits. We will also undertake backwards and forwards citation chasing for eligible articles included in our systematic map.

Bibliographic databases

To support the comprehensive retrieval of relevant studies, we will search the following range of databases listed below. Functionally, Scopus has advanced search with broad, interdisciplinary, and user-friendly interface, which intend us to use it as the main database choice to perform the main search. Web of Science (WoS) is quite similar and represent a good database search choice. Databases will be searched using the “title, abstract and keywords" fields (or equivalent). Some databases (OAIster and ProQuest) search grey literature, others are for fully indexed journal articles. The access will be provided by the lead author’s institutional access, to be reported in the final report. The search will be done using English terms because it is the main language in science search engine like Scopus and WoS. However, the review team has Spanish and Arabic language capacity and full text of articles in these languages (if found) will be included. • Scopus: http://www.scopus.com • WoS- Web of Science – Core Collection: https://mjl.clarivate.com/home • The OAIster database: https://www.oclc.org/en/oaister.html • EBSCO CAB Abstracts: https://www.cabidigitallibrary.org/product/ca • AgEconSearch: https://ageconsearch.umn.edu • ProQuest dissertations and theses: https://www.proquest.com The final search string is documented in Table 1a (Scopus) and Table 1b (WoS) in the appendix 2. Section 8.5 of this protocol further details the rationale, and Appendix 2 contains a full record of the testing associated with the search strategy design.

Web-based search engines

The web-based search engine will include Google, and Google Scholar. Search will be performed in English, Arabic, and Spanish. Search will be carried out using freshwater-wastewater swap and synonyms of the swap. Google search engine: https://google.com Google scholar: https://scholar.google.com We will search the first 200 hits returned from each.

Organisational websites

Specific websites of some international, regional, and national entities will be searched to retrieve grey literature. The sources have been chosen based on subject expertise of the systematic map author/s and stakeholder suggestions. Due to the often-limited functionality of organisation website search facilities, the search string terms will be adapted accordingly, focusing on the FWS element of the systematic map question, like freshwater swap, wastewater swap, intersectoral water exchange, etc. For each organisation search, the method used, search strings, number of hits and number of relevant articles found will be reported in detail in the final report. Where no search function is available, the site will be manually searched. The list of the entities to be searched is presented below. Searches will be done in English language because this is the language of all websites. • The U.S. Environmental Protection Agency (EPA): https://www.epa.gov/. • The Food and Agriculture Organization of the United Nations (FAO): https://www.fao.org/. • The World Bank e-library: https://openknowledge.worldbank.org/home. • The Consultative Group on International Agriculture Research (CGIAR): https://www.cgiar.org/. • CGSpace – CGIAR: https://cgspace.cgiar.org/home. • The World Bank Water in Circular Economy and Resilience (WICER) Initiative platform: https://www.worldbank.org/en/topic/water/publication/wicer. • The Organization of Economic Cooperation and Development (OECD) library https://www.oecd.org/en/publications.html • The European Union publication repository https://op.europa.eu/en/web/general-publications/publications • DATA-IWMI: https://www.IWMI.org • SIDA: https://www.sida.se • WHO: https://www.who.int • UNEP-UN: https://www.unep.org

Comprehensiveness of the search

The search was constructed and tested in the platform Scopus. Question element used for search was the intervention (FWS), because this is the element which is the common denominator in all benchmark articles. Use of other question element was not deemed appropriate due to the wide scope (Population), the non-necessity of the element for inclusion in this systematic map (Comparator), or the focus on sensitivity (Outcome). Extensive testing of combinations of specific terms to describe the intervention, alongside the use of proximity operators (e.g. “within X words of Y”) shaped the search design with iterative testing and recording of results. The document demonstrating this process is available in Appendix 3. A list of 9 benchmark list documents relevant to the map was compiled by subject experts and was used to test the comprehensiveness of the database search (Appendix 4). We acknowledge limitation of 9 being a relatively low number for benchmark list (≥ 10 is usually recommended; CEE guidelines 2022), but the only other known relevant articles were not indexed in Scopus but present in grey literatures. Resulting search hits from each of the tested search string iterations were interrogated to determine whether the 9 articles were present. If a search string did not retrieve an article from the list, we examined why not, and we adapted the search string accordingly to retrieve the whole set of the benchmark list. All 9 articles were retrieved by the final search string (Appendix 1).

Search update

Due to the planned report being produced within 6 months of the searches, along with time and resource limitation, there is no plan to update the searches during the study period.

Screening strategy

Prior to the eligibility screening process of the articles, duplicate articles will be removed from the database search library using references management tools following combination of the search results from search databases. Matching article title, journal name, and authors names will be used to remove duplicates. Articles will be screened by one reviewer (after an initial consistency check- see 9.2), based on eligibility criteria in Table 3 (Appendix 5). The first screening stage will assess articles based on their titles and abstracts, with reviewers being inclusive wherever there is uncertainty or limited information available. The full texts (i.e. PDFs) of articles included at title and abstract will then be retrieved and the articles assessed using the same criteria, again by a single reviewer after a consistency checking phase.

Eligibility criteria

Inclusion and exclusion criteria are present in Appendix 5 and summarized below: Language: Inclusion criteria: • Full text written in English, Spanish, and Arabic will be included, reflecting the team's capacity to extract and analyze data in these languages. Population: • No geographic pr population restriction will be applied; all relevant studies will be considered. Intervention (inter-sectoral FWS). Inclusion criteria: • Any article where there is a clear FWS with freshwater release and substitute by wastewater. • Triangular arrangements are included (where freshwater recipient differs from the alternative water supplier). Exclusion criteria: • Articles that do not have FWS. • FWS within the same sector e.g. within the agricultural sector and industrial water-wastewater exchange. • Effluent reuse/recycle within the same sector as industrial reuse/recycle. • Standalone wastewater reuse, and standalone water conservation. • Intersectoral freshwater transfer (i.e. one way of exchange, not involving a swap). Comparator: • A comparator is not necessary for inclusion, and we anticipate many articles will not contain a comparator. • If a comparator is present, eligible comparators are areas/situations where there are no intersectoral FWS (control-impact studies), or situation before FWS implementation. Outcome: • If present, any measured or anticipated economic, environmental, and/or social costs and benefits or implications. Study type: Inclusion criteria. • Case studies of intersectoral FWS. • Empirical research studies of intersectoral FWS. • Theoretical studies of potential intersectoral FWS. Exclusion criteria: • Review articles, editorials, news articles, and conceptual or opinion pieces proposing FWS without systematic analysis or data.

Consistency checking
During the screening process, a consistency check will be undertaken by selecting a random 10% sample of the articles, which will be screened independently by two reviewers. Any disagreements between the two reviewers regarding eligibility will be checked and any remaining disagreements regarding study eligibility will be resolved by consulting a third reviewer. The outcomes of these discussions will be fully documented. Any resulting clarifications or refinements made to the eligibility criteria, along with the consistency checking data (e.g., agreement rates), will be explicitly reported in the final synthesis. If the level of initial agreement is low (kappa < 0.6) a second set of 10% of records will be independently screened and the process repeated until a score of >0.6 is achieved.

Reporting screening outcomes
The ROSES flow diagram (Haddaway 2017) of the systematic map will be completed to show articles flow through the phases of review process, and the numbers of excluded article will be recorded at each stage of the review. A list of eligible articles and a list of full text of excluded articles (at full text level) and exclusion reasons will be provided as appendix supplemented to the final report.

Study validity assessment
This is a systematic map, and we will not undertake formal study validity assessment.

Consistency checking
This is a systematic map, and we will not undertake formal study validity assessment and thus consistency checking.

Data coding strategy
All eligible articles will be data extracted by 2 reviewers using data extraction form that will be previously prepared and provided to the reviewers. The data extraction form will be provided as appendix with the final report. To align with the objectivity standards, none of the reviewers' team shall extract data from any studies that they are author of, thus, if necessary, a 3rd reviewer will data extract.

Meta-data to be coded
Extracted data will be categorized into top level categories as outlined below and the detailed data coding categories are listed below: General Information. • Full references; authors, title, date, publisher. • Year of publication. • Publication type; academic journal, book, conference paper or thesis. • Article language. • Study country. • State or province. • Date of the study. • Linked study; other articles reporting the same study. Design of the study and key elements. • Experimental, quasi-experimental, observation or survey. • Allocated freshwater sources, surface, or groundwater. • Type of wastewater and level of the treatment. • Type of reuse; agriculture irrigation, landscape irrigation, golf course irrigation, recreational fishing pools or aquaculture reuse. • Type of comparator; if present. • Type of outcome assessed. Regulations, conditions • Regulations (legal, voluntary, state-level) that surround/support/hinder. • Facilitatory conditions (e.g. industry incentives). Outcomes • Economic e.g. reduction in use of artificial fertilizers and reduction in agriculture production cost. • Social e.g. securing water for growing cities enabling a range of recreational water uses • Environmental e.g. nutrients recovery by agriculture reuse minimizing use of artificial fertilizers/ minimizing pollution potential.

Consistency checking
Eligible articles will independently undergo a duplicate extraction process by 2 reviewers, and the results will be cross-referenced to identify any discrepancies. Any discrepancies will be resolved via discussion among the reviewers' team to reach a consensus. The outcomes of the discussion will be

used to further instruct and clarify the data extraction form. In case the primary reviewer cannot extract or code specific data from specific article, the article will be flagged, and all flagged articles will be sent to a 3rd reviewer and later for joint discussion to come with the final decision. This iterative consistency mechanism will ensure all key data are systematically and accurately captured across the whole evidence base.

Type of mapping
Heatmaps will be used to visualize research evidence density across categorical variables e.g. sectors involved in swaps, while evidence atlas will be used to visualize evidence geographically. Network diagrams may be used to display relationships and patterns between authors or authors affiliations. Bar charts and proportion charts will display categorical data, for example, geographical regions represented, date of publication. Final choice of presentation will depend on the extent and shape of the evidence base.

Narrative synthesis methods
The descriptive synthesis aims to identify clusters of evidence, research gaps, and emerging themes within the literature. These descriptive synthesis findings will be presented using summary tables, figures e.g. bar charts, and narrative text to support transparency and facilitate interpretation of the evidence base. We will provide a narrative overview of the available literature, including the geographic distribution of studies, publication trends over time, case study objectives, sectors involved, and types and methods used to undertake the swap. Studies will also be categorized according to key thematic variables identified during data extraction, such as types of water reallocation mechanisms, forms of non-conventional water use, and reported outcomes or applications.

Knowledge gap identification strategy
The tables and graphs will support our identification of knowledge gaps in the evidence base found. We may, for example, identify that there are no documented FWS in certain geographical areas, or that some industries are not involved in FWS in the field. We may also find that there is simply missing information- for example, a lack of documentation of policy environments that may facilitate FWS. We will record and report this in a separate section in the report.

Demonstrating procedural independence
To ensure reviewers team has no role in decision regarding their own publications, strict, pre-defined procedures will be implemented. The reviewers shall disclose all potential conflict of interest, and they will be mandatory recusal from screening and data extraction of their own works and other reviewers will be assigned to undertake this. In the final report, the authors will confirm exclusion of review team members from decisions regarding inclusion or study validity assessment of their own work.

Competing interests
The authors declare that they have no financial or non-financial competing interests.

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Author’s contributions
In cooperation with Eales, Barbra, Enrique, Mohamed O.M., and El-Shafai, Mateo-Silva established the main idea of the systematic evidence map and finance the study via ReWater+ project. Saber A.

in cooperation with Mateo-Silva and Eales developed the search string. Mateo-Silva, Mohamed O.M., Eales and Saber A. share in developing the evidence map protocol.

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