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Review

A Systematic Review on Drivers of Water-Use Behaviour among Agricultural Water Users

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Abstract: Sustainable Development Goal 6 (SDG 6) is closely linked to the sustainable management of water resources and sanitation worldwide. SDG 6.4, in particular, aims to significantly improve water-use efficiency across all sectors by 2030. It is important to acknowledge the significant role that behavioural aspects of water users in an agricultural context play in contributing to water-use efficiency. This systematic review aims to provide an up-to-date synthesis of the current knowledge of water-use behaviours in agriculture to stay on track in achieving SDG 6. This systematic literature review investigates the factors influencing water-use behaviour among agricultural water users globally. Using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) method, we retrieved a total of 867 records, of which 47 matched the eligibility criteria. The 47 relevant studies were primarily conducted in the United States and China with key themes including sustainable agricultural practices, technology adoption for productivity, climate change adaptation, and modelling and uncertainty in water conservation. Additionally, the review identified six distinct water-use behaviours investigated from 2020 to 2024, which were each driven by its unique set of factors. Overall, the findings from the systematic review indicate that there has been a geographical gap in research efforts over the past five years, and it is important for water-use behaviour-related research to be extended to other countries that are water-stressed. Furthermore, the researchers recommend that future studies should develop comprehensive behavioural models and adopt holistic approaches to better understand and promote sustainable water-use behaviours in agriculture. These efforts are vital for achieving sustainable water management and broader SDGs.

Keywords: water resources; water-use efficiency; sustainable agricultural practices; PRISMA; Sustainable Development Goal 6; climate change adaptation

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1. Introduction

On average, agriculture accounts for 70% of global freshwater withdrawals [1]. The per capita distribution of freshwater resources has changed consistently with population growth. Over the 30 years leading up to 2017, food production increased by 100%, and it is estimated that by 2050, a further 60% increase in food production will be necessary to meet the growing global population's food requirements [1,2]. This anticipated higher demand for food in the future is expected to directly affect agricultural water usage, with agricultural production already under threat due to pressures on land and water systems [1].

Against the backdrop of rising food demand, the FAO [2] emphasises the critical role of increasing land and water productivity in achieving food security, sustainable agriculture, and the objectives outlined in the 2030 Agenda for Sustainable Development Goals (SDGs). Among the SDGs, SDG 6 is closely linked to the sustainable management of water resources and sanitation worldwide. SDG 6.4, in particular, aims to significantly improve water-use efficiency across all sectors by 2030. Furthermore, it aims to secure long-term withdrawals and freshwater supplies in order to alleviate water shortages and significantly reduce the number of people affected by water scarcity [3].

Water-use efficiency (WUE) in agriculture has become a critical priority due to the increasing constraints on water resources [4]. This is evident in the research that is directed towards understanding and improving agricultural WUE. For instance, studies have explored water-use efficiency in the context of climate change [5–7], technological innovation [8–10], and agricultural practices [11–15]. Additionally, researchers have studied the dynamics of the environment and their implications on WUE in agriculture [16–18]. Moreover, while studying WUE in light of the aforementioned aspects is important, it is also crucial to acknowledge the significant role that the behavioural aspects of irrigators play in contributing to water-use efficiency. For example, Callejas Moncaleano et al. [19] mentioned that one reason behind inefficient water use is human behaviour.

However, understanding irrigators' water-use behaviour is important even outside of a WUE context. Several studies have emphasised the necessity of tailored policies that account for psychological and behavioural factors (e.g., [20–24]). In addition, understanding water-use-related behaviour is also crucial for water resource management [25]; scaling targeted solutions in agricultural water management challenges [26]; predicting responses to environmental changes accurately [27]; improving environmental programs' effectiveness and efficiency [22]; designing effective strategies to promote water management technique [28]; and facilitating more effective intervention studies for behavioural change [29]. The aforementioned research demonstrates the overall importance of understanding behaviour for sustainable water management.

In addressing the complex interplay between human behaviour and sustainable water management, numerous studies have been undertaken employing various theories and models analysing human environmental behaviours. Callejas Moncaleano et al. [19] provide a comprehensive overview of these models, including the norm activation model (NAM); the new environmental paradigm (NEP); the theory of planned behaviour (TPB); the theory of values; the values, beliefs and norms theory (VBN); the theory of environmentally significant behaviour; and the risk, attitude, norms, abilities and self-regulation (RANAS). Although these conventional behavioural models have been extensively used, they have also been augmented to increase their predictive efficacy [30,31]. For example, studies have augmented the NAM [32–35], TPB [36–41], and the VBN [13,42,43]. The extension of these standard models indicates a growing recognition of the need to refine these models to better capture the complexities of behaviour in specific contexts.

The augmentation of conventional behavioural models is based on either considering potential specific factors or using empirical evidence to guide the augmentation process. In this regard, a literature review on the factors influencing water-use behaviour in agriculture could be a valuable starting point. According to the authors' best knowledge, two reviews [19,44] have been conducted related to the water-use behaviour in agricultural contexts. Callejas Moncaleano et al. [19] reviewed the contextual and behavioural factors influencing water-use efficiency (WUE) and proposed a conceptual framework to link these factors to address the knowledge gaps on human water-use behaviour in light of WUE. The study by Meempatta et al. [44] reviewed the decision-making process of irrigators and the impact of their decisions on resource use, societal welfare, and environmental sustainability. Despite the valuable insights offered by the reviews of Callejas Moncaleano et al. [19] and Meempatta et al. [44], an up-to-date review is crucial to stay on track in achieving SDG 6, particularly target 6.4 (increase water-use efficiency across all sectors) and 6.5 (implement integrated water resources management at all levels). An up-to-date review is especially important, given the rapid advancements in agricultural technologies [45,46], climate change conditions [47,48], and changing social and economic conditions [49,50]. This paper addresses the existing knowledge gap by providing an up-to-date review of the factors influencing water-use behaviour in diverse agricultural contexts. Our review aims to provide an update on the current literature on water-use behaviour in agricultural contexts to ensure that interventions and strategies align with the latest body of knowledge.

2. Materials and Methods

This study will follow the framework developed by Koutsos et al. [51] for systematic reviews that set out a roadmap of guidelines for conducting an effective systematic review for agricultural research. This framework extends the basic steps provided by the PRISMA method. The systematic review framework proposed by Koutsos et al. [51] involves six steps: scoping, planning, identification, screening, eligibility/assessment, and presentation, as outlined in Figure 1.

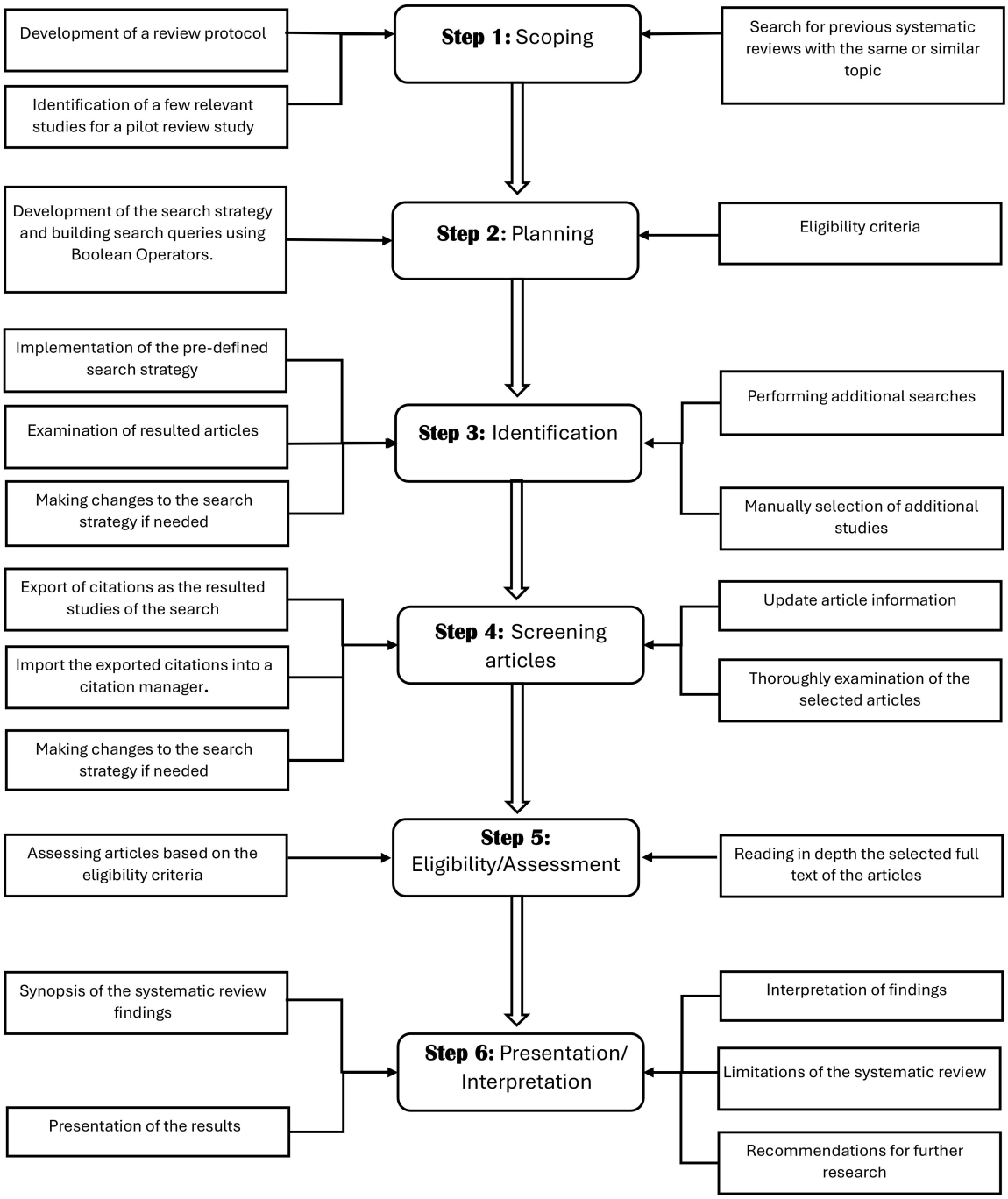


Figure 1. A systematic review framework for agricultural research. Source: Adopted from Koutsos et al. [51].

2.1. Step 1: Scoping

The initial scoping phase is crucial, as it lays the foundation for subsequent stages in the systematic review process. Establishing a robust review protocol involves crafting a detailed research question and study design. We employed the Population, Intervention, Comparison, and Outcome (PICO) framework to structure a clearly defined research question. Table 1 outlines each component of the PICO framework formulated for this systematic review. Our research question is based on the specified PICO elements shown in Table 1: "What are the main factors influencing water-use behaviour among agricultural irrigators globally, taking into account psychological factors, decision-making processes, technological interventions, policy frameworks, and socioeconomic conditions?". Regarding the study design, our systematic review will adhere to the comprehensive protocol proposed by Koutsos et al. [51], which entails six steps, as depicted in Figure 1.

Table 1. PICO elements for a systematic review.

PICO Component	Description
Population	Irrigators involved in water-use practices across various regions and contexts globally.
Intervention	Factors influencing water-use behaviour in agriculture, including but not limited to psychological factors, decision-making processes, technological interventions, policy frameworks, and socioeconomic conditions.
Comparison	Comparisons between different regions, countries, farming systems, and water management approaches
Outcome	Understanding the determinants and patterns of water-use behaviour in agriculture.

Note: Source: Authors' compilation.

Furthermore, the authors involved with this systematic review independently screened and selected studies for inclusion to mitigate bias in study selection and interpretation. The web-based tool Rayyan was utilised to streamline the screening process. Rayyan is widely recognised as an effective tool for speeding up the laborious task of study selection within systematic reviews, fostering collaboration among researchers and boosting productivity [52]. The reviewing process for each reviewer was conducted in a blinded manner, ensuring that they could only view their own decisions and not those of the other reviewers involved.

Figure 2 provides an overview of the systematic integration of Rayyan in our review process. Firstly, search results from relevant databases were uploaded into Rayyan. Subsequently, Rayyan automatically identified duplicates, which the main author carefully managed to ensure the retention of the appropriate version. Following this, independent screening by reviewers took place with each article being categorised as 'Include', 'Maybe', or 'Exclude'. Any discrepancies in categorisation and articles marked as 'Maybe' were thoroughly discussed among the authors to reach a consensus. Once the screening process was completed, subsequent steps in our systematic review could proceed.

A pilot review was conducted to familiarise the authors with the systematic review process and the use of the digital tool Rayyan. The pilot review also helped to refine the search strategy by testing search terms, databases, and inclusion/exclusion criteria and identifying challenges that needed to be resolved before conducting the final review. The pilot review was performed based on the keywords derived from the PICO framework in Table 1. The tailored keywords for each PICO element are presented in Table 2.

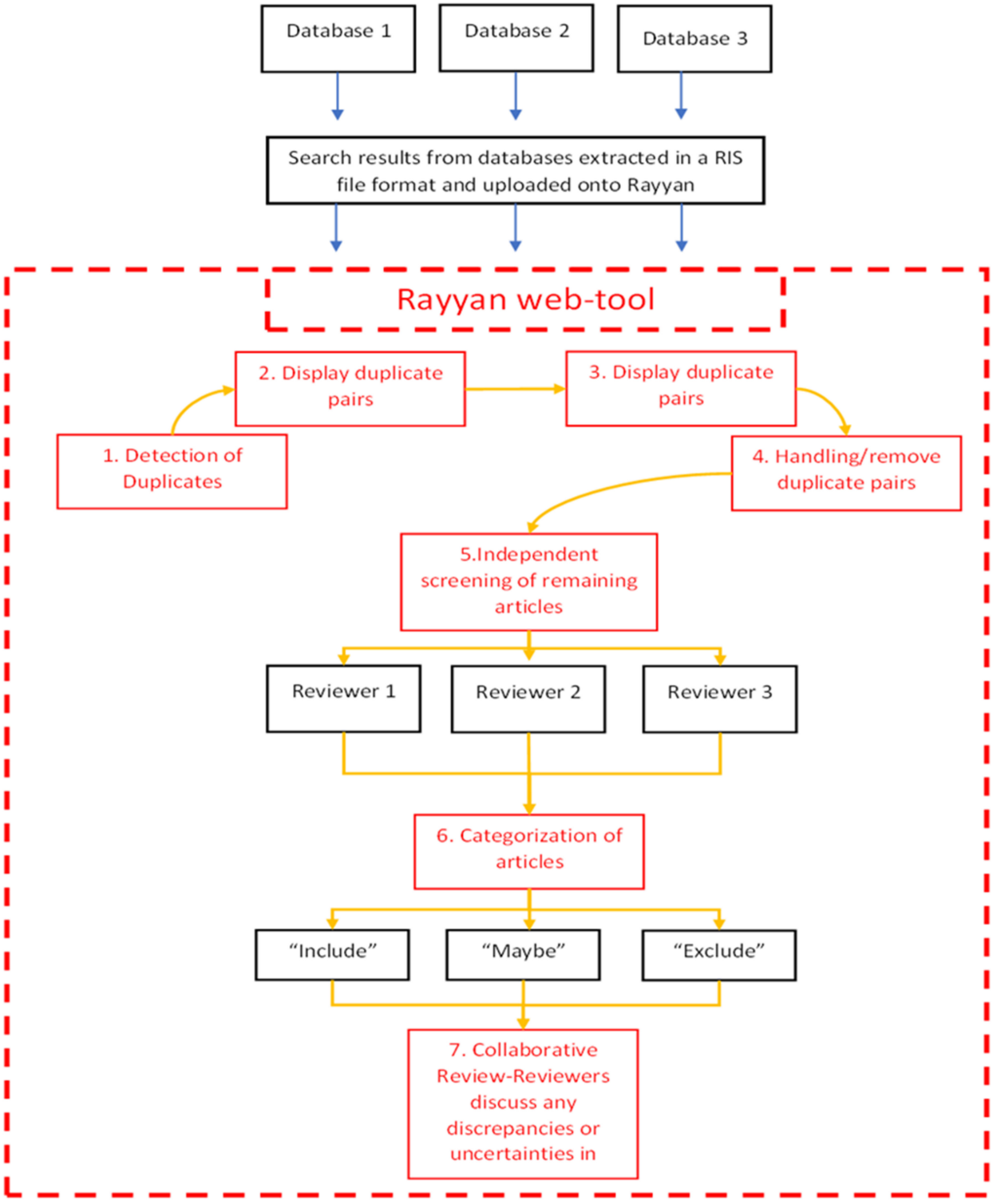


Figure 2. Steps for Rayyan integration in systematic review. Source: Authors' compilation.

Table 2. Specific keywords tailored to each PICO element.

PICO Component	Tailored Keywords
Population	irrigators; farmers; producers; growers; water users; irrigation practitioners; agricultural practitioners; crop growers
Intervention	water use behaviour; water management practices; psychological drivers; irrigation techniques; decision-making; behavioural drivers
Comparison	regional; countries; farming systems; irrigation schemes; water management approaches; farming system variations; international perspectives
Outcome	determinants of water use behaviour; patterns of water use behaviour; water management practices; agricultural water usage patterns; behavioural insights in irrigation

Note: Source: Authors' compilation.

2.2. Step 2: Planning

This study employed a systematic approach to the literature review, utilising Scopus, Web of Science, and EBSCOHost databases (specifically Academic Search Ultimate, Africa-Wide Information, CAB Abstracts with Full Text, E-Journals, GreenFILE, and MEDLINE). Scopus and Web of Science are well known for their coverage of various disciplines [53], whereas EBSCOHost databases provide a wide range of academic resources, including full-text articles, abstracts, and specialised information relevant to the study's aims. Table 3 outlines the specific Boolean operators used for each database to ensure relevant search results.

Table 3. Databases and associated Boolean operators.

Database	Boolean Operators
Web of Science	(farm* or crop or crops or agricultur* or horticultur* or cropland*) and ("water use" or "water usage" or "water management" or "irrigation technique*" or "irrigation management*") and (behav* or pattern* or practice* or insight* or adapt*) and title (manag* or use or usage or technique*) and (water* or irrigat*) and (behav* or pattern* or practice* or insight* or adapt*)
Scopus	(farm* or crop or crops or agricultur* or horticultur* or cropland*) and ("water use" or "water usage" or "water management" or "irrigation technique*" or "irrigation management*") W/5 (behav* or pattern* or practice* or insight* or adapt*) and ti (manag* or use or usage or technique*) and (water* or irrigat*) and (behav* or pattern* or practice* or insight* or adapt*)
EBSCOHost (Academic Search Ultimate, Africa-Wide Information, CAB Abstracts with Full Text, E-Journals, GreenFILE, MEDLINE)	(farm* or crop or crops or agricultur* or horticultur* or cropland*) and ("water use" or "water usage" or "water management" or "irrigation technique*" or "irrigation management*") N5 (behav* or pattern* or practice* or insight* or adapt*)) and ti (manag* or use or usage or technique*) and (water* or irrigat*) and (behav* or pattern* or practice* or insight* or adapt*)

Note: Source: Authors' compilation derived from the keywords identified using the PICO framework. Note: The "*" symbol is a wildcard used to include all variations of a word (e.g., "farm" captures "farm", "farms", "farmer", "farming", etc.).

An additional search was conducted using the advanced search function in Google Scholar. Table 4 outlines the approach followed for this advanced search, detailing the specific search fields and terms used. The results obtained from Google Scholar were exported in ENW file format following the search. These search results were then uploaded to Rayyan for further screening and analysis.

Table 4. Google Scholar additional search protocol.

Google Scholar Advanced Search Field	Description
With all of the words	irrigators farmers water use irrigation
With the exact phrase	behave *
With at least one of the words	producers growers water users irrigation practitioners agricultural practitioners crop growers water management practices psychological drivers irrigation techniques behavioural drivers
Where my words occur	anywhere in the article
Return articles dated between	2020–2024

Note: Source: Authors' compilation derived from the keywords derived from the PICO framework. Note: The "*" symbol is a wildcard used to include all variations of a word (e.g., "behav" captures "behavior", "behaviour", "behaviors", "behaviours", etc.).

2.3. Eligibility Criteria

For the selection of articles, the following inclusion criteria were set: (1) studies published within the last five years (2020 to 2024) to ensure the relevance of the research; (2) all studies published in peer-reviewed English language journals; (3) studies that investigate various interventions or practices related to water use in agriculture; (4) studies involving farmers, agricultural workers, or any individuals directly involved in agricultural activities related to water use will be considered; and (5) peer-reviewed papers, reports, and relevant publications that meet the criteria for eligibility will be included.

To ensure that the papers included in this systematic review are relevant, the following exclusion criteria were established: (1) book chapters were omitted to keep the focus on peer review articles; (2) papers that were work-in-progress or labelled as "short papers" were excluded; (3) to ensure that this systematic review does not duplicate existing secondary literature captured in other review types (such as scoping reviews, critical reviews, narrative reviews, opinion pieces, and systematic reviews), we specifically excluded these review types. Our systematic review focuses exclusively on primary studies, avoiding the duplication of research already covered by other systematic reviews; (4) studies not focused on water-use behaviour in agricultural contexts were also excluded; and (5) theses and dissertations are excluded from consideration to maintain consistency with the focus on peer-reviewed articles.

2.4. Step 3: Identification/Search

The predefined search queries were executed, and the results were exported. For the databases listed in Table 3, the search results were exported in RIS file format, and for Google Scholar (Table 4), the search results were exported in EWN file format. Both RIS and EWN file formats are compatible with Rayyan. The results were then uploaded and briefly scanned in Rayyan to confirm their relevance before proceeding with in-depth screening in the next step. During this initial screening, it was ensured that the search results accurately reflected the intended scope of the review. No additional changes were made to the search terms, as the formulated strategy was comprehensive and aligned with the keywords derived from the PICO framework.

The reporting of this systematic review was guided by the standards of the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) Statement (Figure 3). We retrieved 867 records, of which 709 were obtained from electronic databases (WOS, Scopus, and EBSCOHost), and 158 additional records were obtained from Google Scholar. After removing 361 duplicates, 506 records remained for screening of their titles and abstracts.

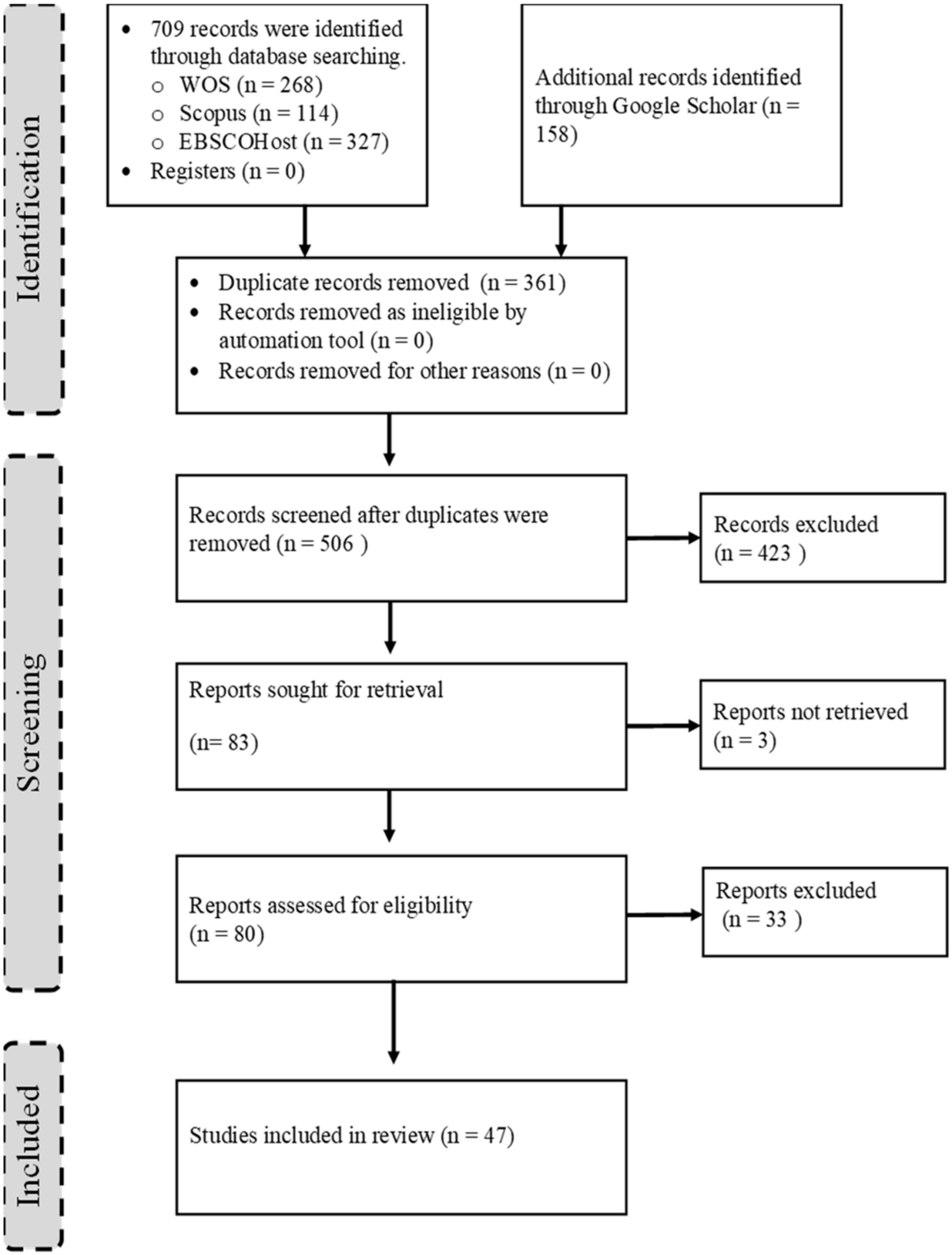


Figure 3. PRISMA flow chart to illustrate the article search and the inclusion process. Source: Authors' compilation based on Page et al. [54].

2.5. Step 4: Screening Articles

At this stage, each reviewer categorised the 506 records in Rayyan as either "include", "exclude", or "maybe" based on their titles and abstracts (see Figure 3). Out of the 506 records, 381 were marked as "exclude", while 71 were classified as "include". Additionally, 31 records were tagged as "maybe", and 23 records had conflicting classifications among the authors. The authors engaged in discussions to reach an agreement for the 31 "maybe" records and the 23 conflicting records. Eventually, 7 out of the 31 "maybe" articles and 5 out of the 23 conflicting records were included in the final analysis. Therefore, a total of 83 records remained to be assessed for eligibility.

2.6. Step 5: Eligibility/Assessment

The 83 articles that remained after the title and abstract screening were chosen for full-text analysis. Initially, attempts were made to retrieve the full texts of all articles. However, full texts for 3 out of the 83 articles could not be obtained, because access to these articles required payment that was not within our financial resources. Therefore, a total of 80 full-text records were evaluated against the predefined eligibility criteria to determine whether they aligned with the objectives of this study. A total of 33 articles were not deemed suitable and were removed based on the criteria, which resulted in 47 articles being considered eligible.

Based on the methodology described by van Dinter et al. [55], a quality assessment of the 47 articles was carried out to ensure that this systematic review maintained an acceptable standard. Table 5 displays the detailed criteria used to evaluate the quality of all 47 studies. The colour-coded system used in Appendix A, Table A1, shows how well each article met each criterion. Studies below a score of 4 out of 8 were removed, while those with a higher score were kept, ensuring high-quality input for our systematic review. Nevertheless, no studies scoring below four were identified, meaning the total number of articles to be included in our systematic review remained at 47.

Table 5. Quality checklist.

Quality Criteria	Question
Q1	Are the aims of the study clearly stated?
Q2	Are the scope, context and experimental design clearly defined?
Q3	Are the variables in the study likely to be valid and reliable?
Q4	Is the research process documented adequately?
Q5	Are all the study questions answered?
Q6	Are the negative findings presented?
Q7	Are the main findings regarding creditability, validity, and reliability clearly stated?
Q8	Do the conclusions relate to the purpose of the study? Are they reliable?

Note: Source: Adopted from Dinter et al. [55].

3. Results

This section provides a detailed analysis of the findings from our systematic review, offering insights into their interpretation and the broader implications drawn from the literature.

3.1. Publication Trends

In this review, the 47 articles selected for inclusion are summarised in Appendix A, Table A2. Table A2 provides an overview of the authors of each study, the year of publication, the country where the study was conducted, the type of water-use behaviour examined, and a summary of the key findings of each study. The year of publication for the 47 studies is illustrated in Figure 4. The publication output varied from 2020 to 2024, with

the highest number of publications observed in 2021 and 2022, each of these years totalling 15 publications. Notably, the low number of publications in 2024 can be attributed to the fact that the searches for this systematic review were conducted in March 2024 and that publications in 2024 would likely increase after this systematic review.

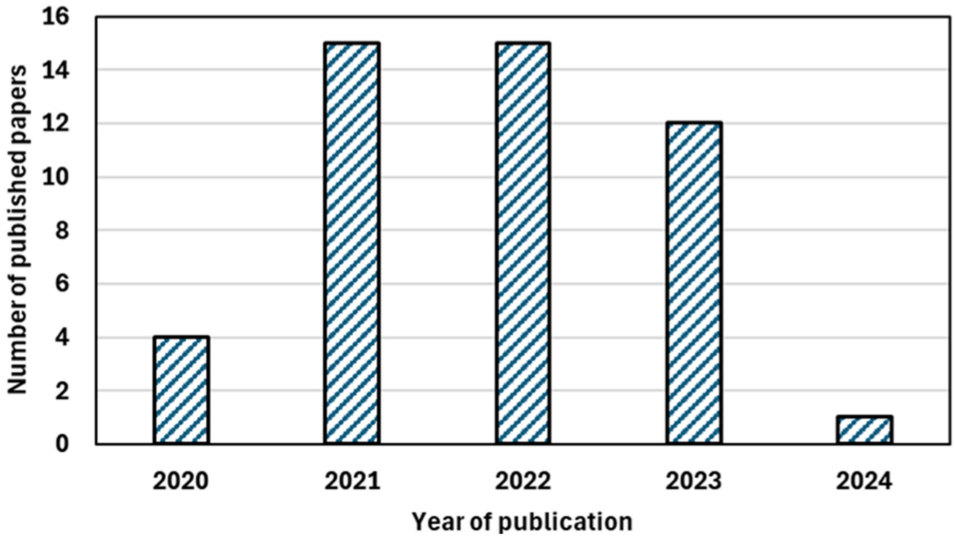


Figure 4. Number of papers published in each year over the five years (2020–2024). Source: Authors' compilation.

3.2. Geographic Distribution of Studies

The treemap shown in Figure 5 visually summarises the distribution of study counts across different countries within the final 47 articles identified. In Figure 5, the size of each rectangle in the treemap corresponds to the number of studies conducted in that specific country. The United States and China are the top countries in terms of research numbers on water-use behaviour in agriculture: the United States conducted eight studies, while China conducted seven studies between 2020 and 2024.

Furthermore, we employed keyword co-occurrence analysis to examine the thematic focus of water-use behaviour studies conducted in the U.S. (8 studies) and China (7 studies). The analysis was conducted using Nvivo 14 software, and density visualisation plots were derived from the results. Separate density plots were created for the eight studies conducted in the U.S. (Figure 6) and the seven studies in China (Figure 7). These density plots highlight the predominant themes emerging from each country's research on water-use behaviour in agricultural contexts, enabling a comparative analysis between the U.S. and China.

The density visualisation plot (Figure 6) for the eight studies conducted in the U.S. reveals how research efforts have focused on understanding and enhancing water-use behaviour in agricultural contexts. Key themes such as "water conservation", "soil moisture sensors", "irrigation management", and "agriculture" indicate that these topics have been prominent in the studies analysed. Additionally, there is increasing attention towards "climate change beliefs", "adaptation", and "irrigation", underscoring a growing recognition of climate impacts and the necessity for adaptive strategies in agricultural water management. The visualisation where "water conservation" is the largest and bright red, close to nodes like "soil moisture sensors", "agriculture", and "irrigation", suggests strong connections and frequent co-occurrences among these concepts in eight U.S. studies. Furthermore, the connection between "climate change beliefs" and "adaptation" suggests that U.S. farmers' perceptions and beliefs about climate change are an important factor shaping their adaptive behaviours and water-use practices.

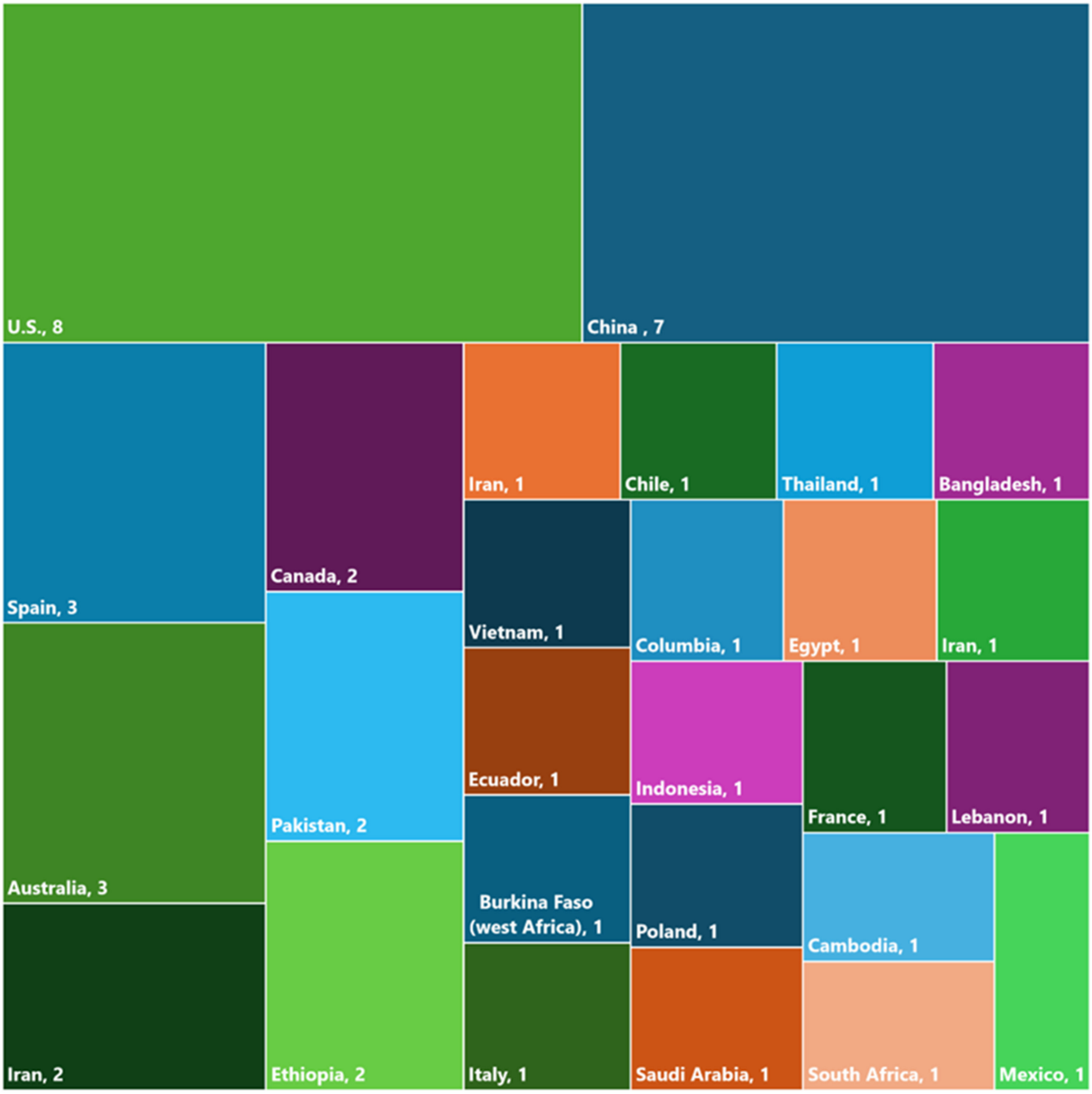


Figure 5. Treemap of study distribution across countries (2020–2024). Source: Authors' compilation.

The keyword co-occurrence analysis of the seven studies on water-use behaviour in China, shown in Figure 7, reveals six significant keywords. The analysis highlights "management" as the largest and brightest node, closely linked to "scarcity", indicating a strong research focus on managing water resources in response to scarcity issues in China. This underscores significant efforts in developing and implementing management strategies to address water scarcity challenges. The proximity of nodes for "determinants" and "land" suggests a strong relationship between factors influencing water use and land-related issues. Furthermore, "smallholder farmers" is closely located to "land", emphasising the importance of land use practices by smallholder farmers in research. This clustering shows recent research emphasis on understanding the various determinants and land management practices, particularly involving smallholder farmers, in studies conducted in China.

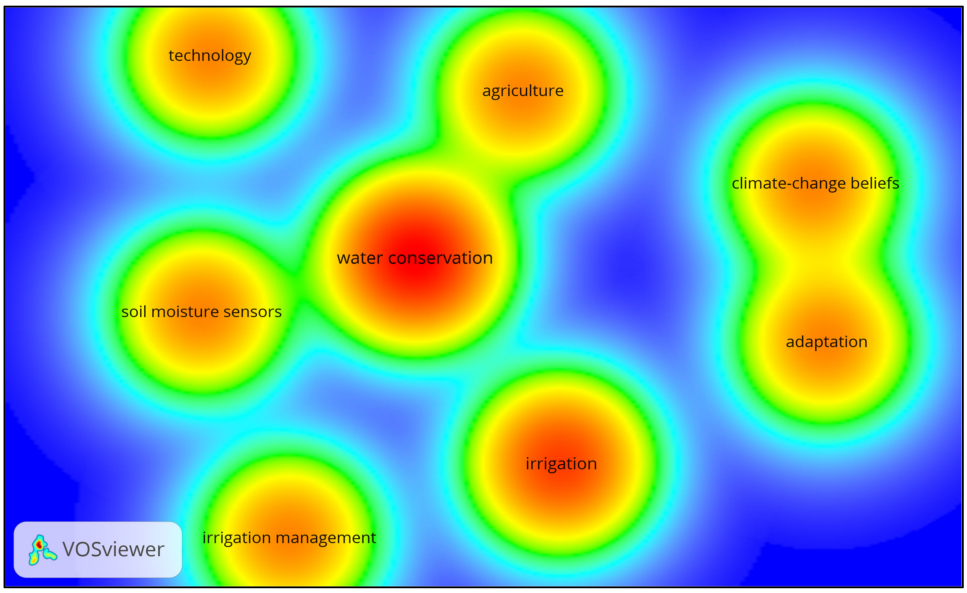


Figure 6. Bibliometric network analysis of agricultural water-use behaviour studies conducted in the U.S. Source: Authors' compilation. Note: Nodes represent keywords extracted from the literature. Larger and brighter nodes indicate keywords that appear more frequently or are central to the network. Connections (edges) between nodes represent co-occurrences of keywords within the selected studies. The colour scheme in the density visualization plot ranges from bright red to blue. Key nodes are represented in bright red, indicating higher density or significance, while the surrounding areas are shaded in blue, showing lower density or significance.

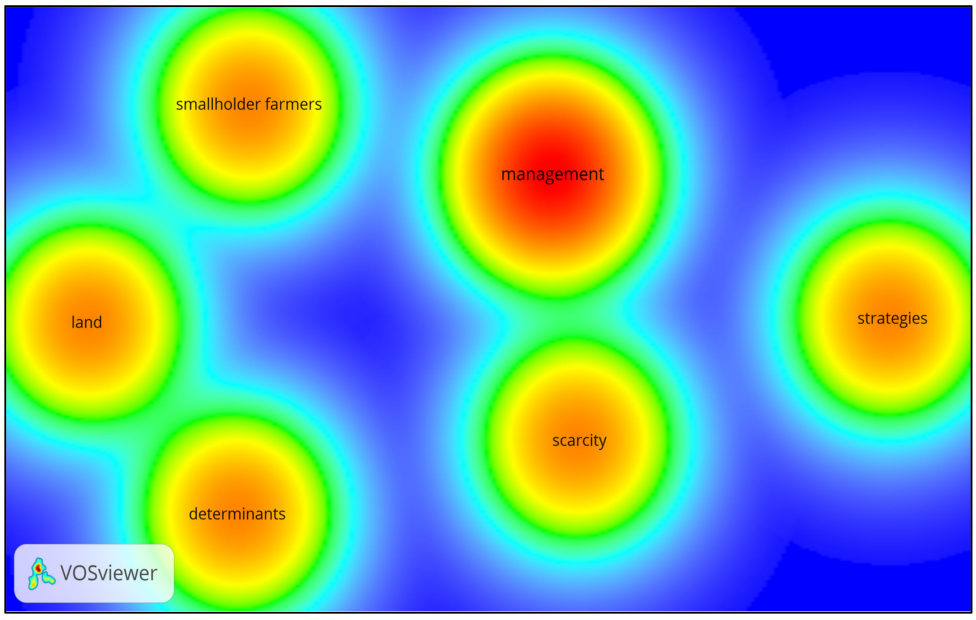


Figure 7. Bibliometric network analysis of agricultural water-use behaviour studies conducted in China. Source: Authors' compilation. Note: Nodes represent keywords extracted from the literature. Larger and brighter nodes indicate keywords that appear more frequently or are central to the network. Connections (edges) between nodes represent co-occurrences of keywords within the selected studies. The colour scheme in the density visualization plot ranges from bright red to blue. Key nodes are represented in bright red, indicating higher density or significance, while the surrounding areas are shaded in blue, showing lower density or significance.

The density visualisation plots provide a detailed overview of the main themes and concepts explored in research on water-use behaviour in the U.S. and China. To complement these insights, Appendix A, Table A3 summarises the key topics addressed in each study.

Table A3 shows that studies on water-use behaviour in Chinese agriculture cover key topics such as government policies and social security measures affecting water-management practices; the implementation and impact of water pricing policies; farmers' decision-making processes and risk preferences; adoption of water-saving technologies; the role of social networks and economic incentives in water management strategies; and awareness of environmental consequences related to agricultural water use. These topics reflect the diverse factors influencing water-use behaviours and strategies in Chinese agriculture.

Furthermore, Table A3 reveals that studies on water-use behaviour in U.S. agriculture explored key topics such as irrigation practices and scheduling, the adoption of water conservation technologies, multilevel modelling of water-use behaviour, and policy implications of water conservation efforts. Overall, Table A3 highlights the different regional priorities and challenges faced by farmers in the U.S. and China.

3.3. Key Theme and Topics

Next, a word frequency analysis was conducted using Nvivo 14 software to identify key themes and focus areas discussed across the 47 articles included in this systematic review. Figure 8 presents the word frequency cloud derived from the full-text body of the 47 articles and places greater prominence on words that occurred most frequently across the 47 articles. The words "climate", "irrigation", "water", "change", "farmers", and "adoption" were found to be the most frequently occurring words expressed in red, indicating that these words occurred with the highest frequency.



Figure 8. Word frequency cloud derived from the full 48 documents included in this systematic review. Source: Authors' compilation. Note: Words in the centre are the largest and appear in red, indicating the highest frequency. These central words are surrounded by slightly smaller words in bold black, representing moderate frequency. The bold black words are further surrounded by smaller words in grey, indicating lower frequency.

In addition to the insights obtained from Figure 8, a word frequency table (Table 6) was constructed to provide a deeper understanding of the most prominent words identified across the 47 articles in this review. Table 6 displays the top 30 words based on their frequency in the 47 articles, giving an overview of their occurrence. From Table 6, the top three words by frequency are "water", "irrigation", and "farmers", with high word counts of 7674, 4270, and 2783, respectively. The word "water" has a weighted percentage of 2.01%,

meaning it makes up 2.01% of all words across the 47 articles. Furthermore, the ranking of words in the top ten of occurrence, such as "farmers", "adoption", and "management", highlights the vital role of agricultural practitioners in adopting water-saving methods and efficiently managing water resources. In addition, the inclusion of words such as "climate" and "change" suggests a growing concern regarding the impacts of climate change on water resources and agricultural practices.

Table 6. Word frequency.

Word Ranking	Word	Length	Count	Weighted Percentage	Word Ranking	Word	Length	Count	Weighted Percentage
1	water	5	7674	2.01	16	crop	4	1001	0.26
2	irrigation	10	4270	1.12	17	risk	4	888	0.23
3	farmers	7	2783	0.73	18	data	4′	873	0.23
4	climate	7	1817	0.47	19	information	11	847	0.22
5	change	6	1679	0.44	20	level	5	845	0.22
6	adoption	8	1659	0.43	21	factors	7	828	0.22
7	management	10	1589	0.42	22	research	8	823	0.22
8	agricultural	12	1558	0.41	23	saving	6	817	0.21
9	farm	4	1344	0.35	24	land	4	816	0.21
10	farmers'	8	1310	0.34	25	soil	4	790	0.21
11	adaption	10	1276	0.33	26	used	4	789	0.21
12	technology	10	1216	0.32	27	area	4	758	0.20
13	model	5	1176	0.31	28	variables	9	749	0.20
14	study	5	1138	0.30	29	agriculture	11	744	0.19
15	practices	9	1042	0.27	30	policy	6	740	0.19

Note: the weighted percentage in a word frequency query assigns a portion of the word's frequency to each group to ensure the overall total does not exceed 100%. Source: Authors' compilation.

3.4. Keyword Co-Occurrence Network

The word frequency cloud (Figure 8) and Table (Table 6) highlight several key themes covered across the literature: water management and irrigation; farmers and their perceptions; climate change and its impacts; and agricultural practices, management, and technology adoption.

In addition, further insights were gained by constructing a keyword co-occurrence network (Figure 9) to identify key themes, clusters, and connections within our included studies. The keyword co-occurrence network was generated in Vosviewer, where 383 keywords were extracted, among which 33 keywords meet the threshold of three, meaning that the minimum occurrence of a keyword is three. Each node in Figure 9 represents a keyword with the size of the node indicating the frequency of occurrence of that keyword. Larger nodes signify keywords that are more significant within the corpus. The distance between nodes reflects the relatedness of keywords based on their co-occurrence, where nodes closer to each other indicate that keywords appear together more frequently in the same articles. The thickness of the lines between the nodes indicates the strength of the co-occurrence relationship. Furthermore, keywords are grouped into clusters that are thematically connected. Additionally, the colour of each node denotes the cluster to which the keyword belongs, and the words within each cluster tend to co-occur more frequently with each other than with words in other clusters.

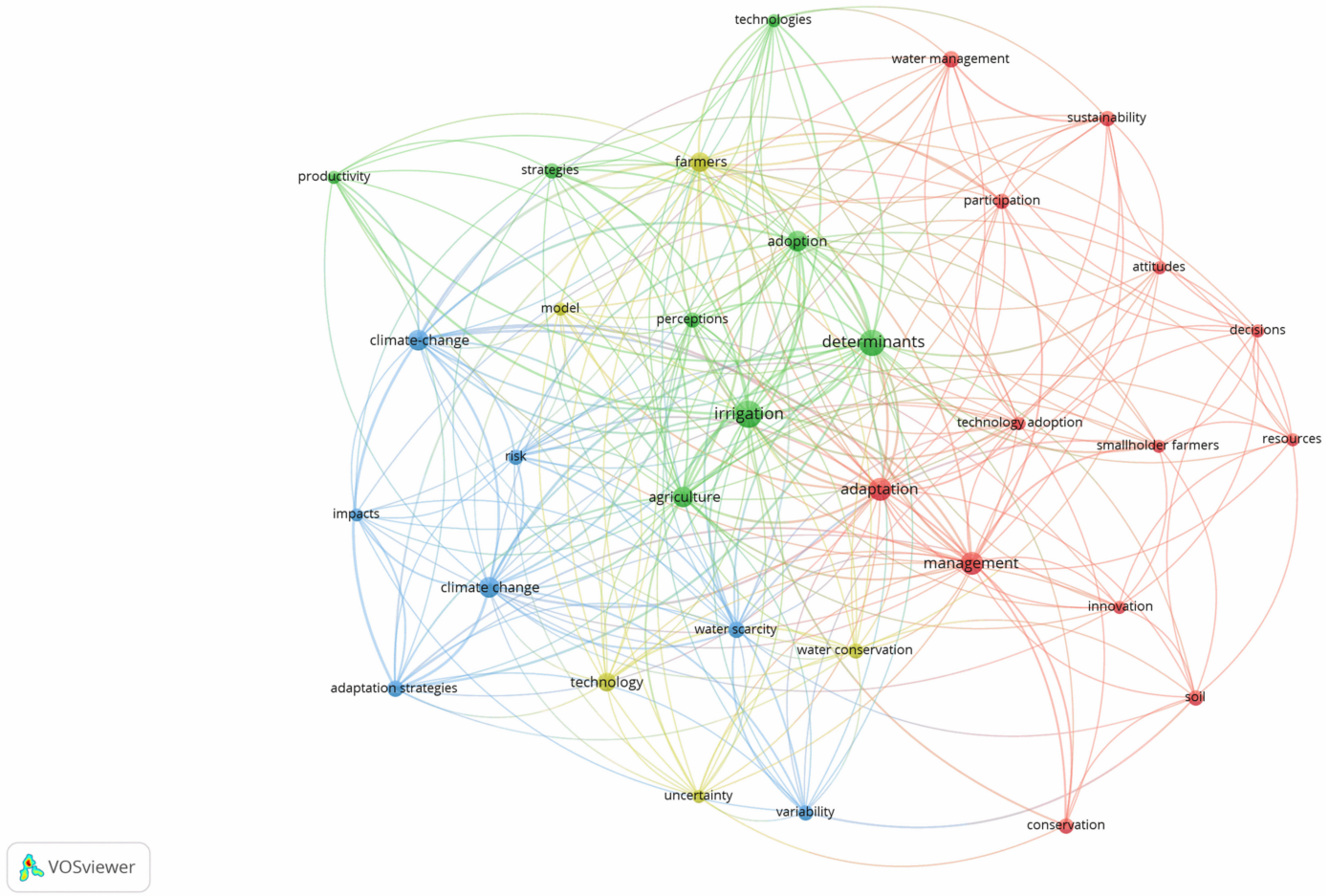


Figure 9. Keyword co-occurrence network. Source: Authors' compilation. In the keyword co-occurrence network, the different colours represent different clusters. Each cluster indicates a group of keywords that frequently occur together, highlighting related themes or topics within the dataset.

A total of four clusters occurs in Figure 9, each with distinct colours. In the first cluster (red), keywords such as "adaptation", "conservation", "innovation", "management", "sustainability", and "water management" are all related to sustainable agricultural practices and resource management. In the second cluster (green), keywords such as "adoption", "agriculture", "irrigation", "productivity", and "technologies" are all associated with the adoption and use of technologies in agriculture to improve productivity, particularly in water management. Conversely, phrases like "climate change", "adaptation strategies", "impacts", "risk", and "water scarcity" are included in the third cluster (blue), suggesting a thematic emphasis on understanding and addressing the impacts of climate change on water availability and agricultural practices. Lastly, the fourth cluster (yellow) highlights keywords such as "farmers", "model", "technology", "uncertainty", and "water conservation", suggesting a thematic focus on modelling approaches and uncertainties in agricultural water management.

Viewing the interlinkages between clusters in Figure 9 reveals that "adaptation" (cluster one, red) is closely linked to "irrigation" and "agriculture" (cluster two, green), which implies that efficient irrigation practices are an important component of adaptive strategies in agriculture. In addition, "adaptation" (cluster one, red) is also linked to "climate change" and "impacts" (cluster three, blue), which highlights the need for adaptive strategies to mitigate the adverse effects of climate change and the related impacts of climate change.

3.5. Types of Water-Use Behaviours Investigated

Furthermore, a detailed breakdown of the various specific water-use behaviours investigated across the 47 studies was provided. From the 47 articles, a total of six distinct categories of water-use behaviour have been identified. The following categories of behaviours were used: (1) adaptation to climate change; (2) adoption of water-saving technologies; (3) adoption of water conservation techniques/practices; (4) complying with water-saving policies; (5) water-use behaviour in light of institutional performance; and (6) seasonal irrigation water usage patterns. A sunburst chart (Figure 10) was created to visually represent the distribution of studies across the six water-use behaviour categories. It is important to note from Figure 10 that some studies address multiple water-use behaviours. Figure 10 reveals that the adoption of water conservation techniques/practices (behaviour 3) emerges as the dominant focus among the identified water-use behaviours, with a notable 24 studies dedicated to this specific behaviour. Following closely, the adoption of water-saving technologies (behaviour 2) emerges as another prominent behaviour investigated with 17 studies dedicated to studying the adoption of water-saving technologies. However, the remaining five water-use behaviours identified (behaviours 1, 4, 5, and 6) received considerably less attention. Specifically, six studies focused on adaptation to climate change (behaviour 1), while four studies examined compliance with water-saving policies (behaviour 4). Additionally, only one study examined water-use behaviour in relation to institutional performance (behaviour 5), and similarly, only one study focused on seasonal irrigation water usage patterns (behaviour 6).

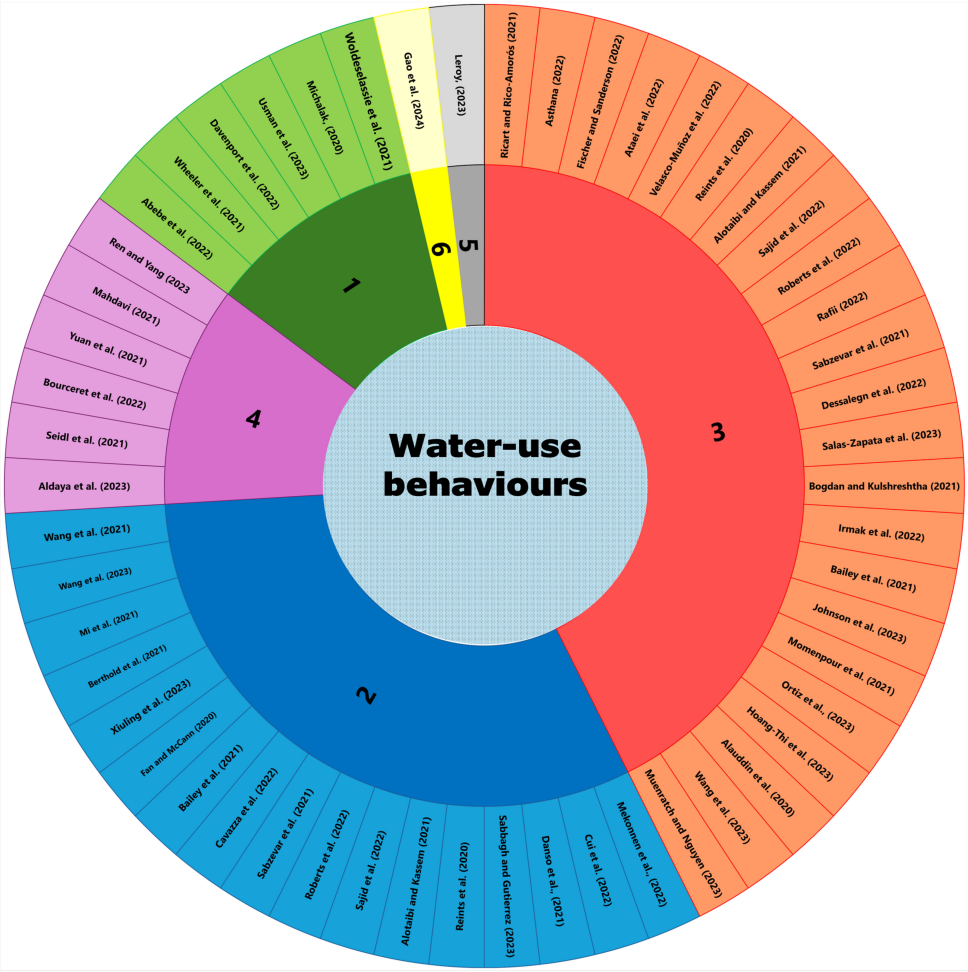


Figure 10. Distribution of studies across water-use behaviour categories. Source: Authors' compilation. Note that the number in the middle layer of the sunburst chart represents a specific water-use

behaviour: (1) adaptation to climate change; (2) adoption of water-saving technologies; (3) adoption of water conservation techniques/practices; (4) complying with water-saving policies; (5) water-use behaviour in light of institutional performance; and (6) seasonal irrigation water usage patterns. Note: Alotaibi and Kassem [20]; Ataei et al. [21]; Bourceret et al. [22]; Seidl et al. [24]; Yuan et al. [25]; Dessalegn et al. [26]; Sabzevar et al. [27]; Sabbagh and Gutierrez [28]; Wang et al. [41]; Woldeselassie et al. [56]; Michalak [57]; Usman et al. [58]; Davenport et al. [59]; Wheeler et al. [60]; Abebe et al. [61]; Wang et al. [62]; Mi et al. [63]; Berthold et al. [64]; Xiuling et al. [65]; Fan and McCann [66]; Bailey et al. [67]; Cavazza et al. [68]; Roberts et al. [69]; Sajid et al. [70]; Reints et al. [71]; Danso et al. [72]; Cui et al. [73]; Mekonnen et al. [74]; Muenratch and Nguyen [75]; Alauddin et al. [76]; Hoang-Thi et al. [77]; Ortiz et al. [78]; Momenpour et al. [79]; Johnson et al. [80]; Irmak et al. [81]; Bogdan and Kulshreshtha [82]; Salas-Zapata et al. [83]; Rafii [84]; Velasco-Muñoz et al. [85]; Fischer and Sanderson [86]; Asthana [87]; Ricart and Rico-Amorós [88]; Ren and Yang [89]; Mahdavi [90]; Aldaya et al. [91]; Leroy [92]; Gao et al. [93].

Next, the six water-use behaviours in Figure 10 were further analysed by exploring the driving factors behind each behaviour as identified in the relevant studies. Considering the diverse agricultural contexts reflected across the 47 studies, a deeper understanding of the variables that have been found to influence each water-use behaviour will provide valuable insights into the broad spectrum of determinants driving water-use behaviours in diverse agricultural landscapes. It is clear from Figure 11 that the variables found to influence climate change adaptation in agricultural water-use-related contexts are multifaceted. Farmers' ability to implement adaptive measures has been found to be influenced by economic and financial factors, institutional and information access, farm characteristics and resources, sociodemographic factors, and perceptions and experience. The economic and financial factors identified include cost and availability of resources [56], financial resources [57], debt levels [60], debt-to-equity ratios [60], and access to credit [58,61]. Institutional and information access factors encompass support from government institutions [57], access to information [57], information on weather forecasting [60], information on climatic and natural hazards [58], and agricultural extension services [58,61]. Farm characteristics and resources include crop characteristics and requirements [56,60], irrigation timing and frequency [56], supplemental irrigation [56], crop type [57], farm size [57,58,60,61], tenancy status [58], irrigated area [60], and soil quality [58]. Sociodemographic factors are age, education, and household size [58]. Lastly, perception and experience factors involve future drought exposure belief [59], farm sensitivity appraisal [59], drought risk perception [59], climate change perceptions [59,61], and previous adaptation experience [61].

The results in Figure 12 indicate that the implementation of water-saving techniques (water-use behaviour 2) is impacted by a range of factors such as demographic and socioeconomic variables, awareness and perceptions, institutional and policy influences, environmental and farm characteristics, psychological and behavioural elements, information access, and interaction and collaboration. Demographic and socioeconomic variables include education level [62,64,65,67,70], off-farm work participation [62], household income level [67], age [28,64,65,71], family size [73], and health [68]. Awareness and perceptions encompass environmental awareness [41], water scarcity perception [27], perceived ease of use of technology [41], knowledge about water management [27], awareness towards water pollution and disasters [20,73], and awareness of water management interventions [70]. Institutional and policy factors comprise access to extension services [62,69], subsidies [63,70,72], cooperative membership [63], and supportive policies [68]. Environmental and farm characteristics involve crop types [20,66,67], irrigation practices [67], planting scale [63,73], regional climates [71], income from crops [71], farm size [65,66,70], irrigation complexity [71], climate variability [66] and seasonal precipitation patterns [67]. Psychological and behavioural elements include subjective norms [41], attitudes [27,41], perceived control [41], self-efficacy and risk-taking [27], effort, and performance expectancy [28,69]. Informational variables include general access to information [27,66] and access to reliable data [64]. Interaction and collaboration include neighbours' decisions [63], coordination and cooperation

among relevant actors [68], friendships among irrigators [74], spatial proximity between farms [74], and shared knowledge among farmers [74].



Figure 11. The factors influencing adaptation to climate change in agricultural water-use contexts. Source: Authors' compilation. Note: Woldeselassie et al. [56]; Michalak [57]; Usman et al. [58]; Davenport et al. [59]; Wheeler et al. [60]; Abebe et al. [61].

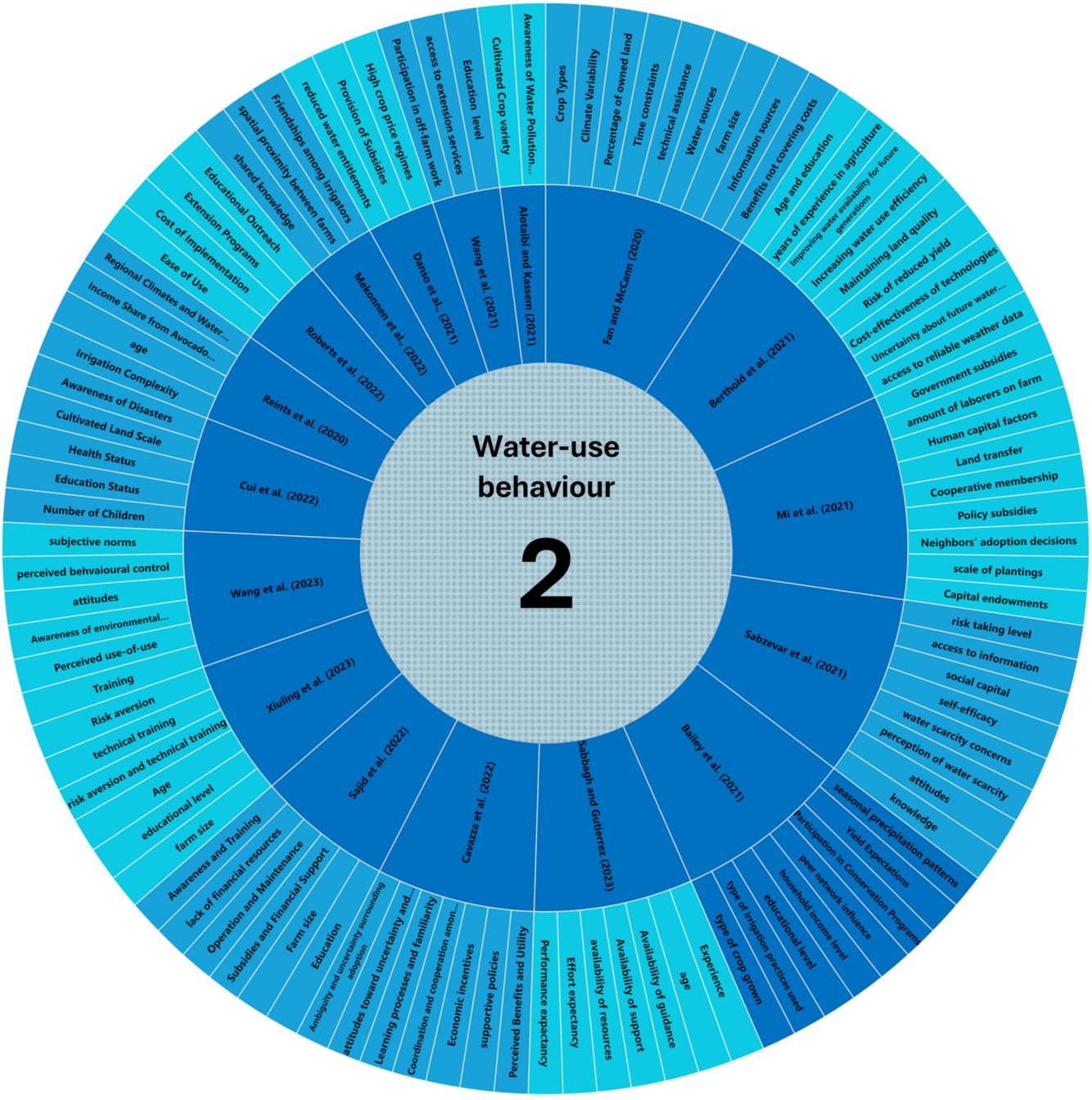


Figure 12. Factors influencing the adoption of water-saving technologies in agricultural water-use contexts. Source: Authors' compilation. Note: Alotaibi and Kassem [20]; Sabzevar et al. [27]; Sabbagh and Gutierrez [28]; Wang et al. [41]; Wang et al. [62]; Mi et al. [63]; Berthold et al. [64]; Xiuling et al. [65]; Fan and McCann [66]; Bailey et al. [67]; Cavazza et al. [68]; Roberts et al. [69]; Sajid et al. [70]; Reints et al. [71]; Danso et al. [72]; Cui et al. [73]; Mekonnen et al. [74].

The adoption of water conservation techniques/practices (Figure 13) in agricultural contexts is influenced by a wide range of variables that can be categorised into several key areas. Demographic and socioeconomic factors play a significant role, including variables such as age and education level [67,70,71,76,82,83], household income [77,80], household assets [77], land ownership [76,82], and gender [26,80]. Awareness and perception variables were also found to be significant with influences including environmental knowledge [27,75,84], awareness of extraction impacts and environmental consequences [20,41,75,85,87], perception of climate change and water scarcity [27,77,80], and

perceived water availability [80]. The third category of variables focuses on technological, institutional and policy factors, which encompass groundwater tariffs [75], training programs [41,70], institutional factors [26,79,80], and supportive regulations and policies [26,81]. Informational variables were also significant, including access to prior weather information [76], general information [67], and access to information [27]. The next category identified focuses on environmental and farm characteristics, including topography and soil type [69,76,79], irrigated land area, elevation, rainfall [77,81], climatic conditions [80], farm size and location [70,78,82,83,88], water quality and context [26,86,88], and cultivated crop variety [20]. Another crucial category identified is the psychological and behavioural factors, which entail variables such as subjective norms [21,41,75], perceived behavioural control [41,75], attitudes [21,27,41,84], self-efficacy [84], personal norms and intentions [21], and environmental values [86]. Lastly, the adoption of water conservation techniques/practices was found to be influenced by interaction and collaboration factors, including social networks [85], social norms [21], social capital [27], and other social factors [79]. These categories collectively highlight the complex interplay of factors that drive the adoption of water-saving technologies in agriculture.

Figure 14 summarises the factors influencing compliance with water-saving policies in agricultural water-use contexts. Farm characteristics, including farm productivity [24,89], farmland value and excess water holdings [24], farm area under irrigation [24], soil type and agronomic factors [91], and mobility of resource units [89] have been found to play an essential role in farmers' decisions to comply with water-saving policies. In addition, economic factors were also found to be important, such as farm financial metrics [24,25,91], labour considerations [91], water pricing, and market conditions [91]. Environmental factors are also crucial determinants, encompassing climatic variables and precipitation levels [25,91], regional variations in water resources [89], and territorial features [91]. Furthermore, psychological and behavioural aspects were also identified as important, entailing factors such as attitudes [22,90], subjective norms [22,90], perceived behavioural control [22,90], adventurous perceptions and tolerance for profit variation [25]. Moreover, demographic and socioeconomic dimensions, including gender and education levels [24], were found to be significant. Perceptions related to climate change risks were also found to act as a significant driver [24].

The remaining two water-use behaviours (behaviours 5 and 6) are illustrated together in Figure 15, since only one study has been found for each of these behaviours. In light of water-use behaviour 5 (institutional performance), the categories of influencing variables include farm characteristics (location within the irrigation scheme/area, access to groundwater), interaction and collaboration (social capital, group size of irrigators in specific regions), technological and institutional (irrigation technique used, organisation and association membership) and awareness and perception (perceptions of fairness in water distribution, perceptions of water scarcity) [92]. For seasonal irrigation water usage patterns (behaviour 6), the influencing variables include farm characteristics (soil properties, crop type), technological factors (number of irrigation days in the season, early-season irrigation intensity, duration of the irrigation period), and environmental factors (climate predictors) [93].



Figure 13. Factors influencing the adoption of water-saving conservation techniques/practices in agricultural water-use contexts. Source: Authors' compilation. Note: Alotaibi and Kassem [20]; Ataei et al. [21]; Dessalegn et al. [26]; Sabzevar et al. [27]; Wang et al. [41]; Bailey et al. [67]; Roberts et al. [69]; Sajid et al. [70]; Reints et al. [71]; Muenratch and Nguyen [75]; Alauddin et al. [76]; Hoang-Thi et al. [77]; Ortiz et al. [78]; Momenpour et al. [79]; Johnson et al. [80]; Irmak et al. [81]; Bogdan and Kulshreshtha [82]; Salas-Zapata et al. [83]; Rafii [84]; Velasco-Muñoz et al. [85]; Fischer and Sanderson [86]; Asthana [87]; Ricart and Rico-Amorós [88].

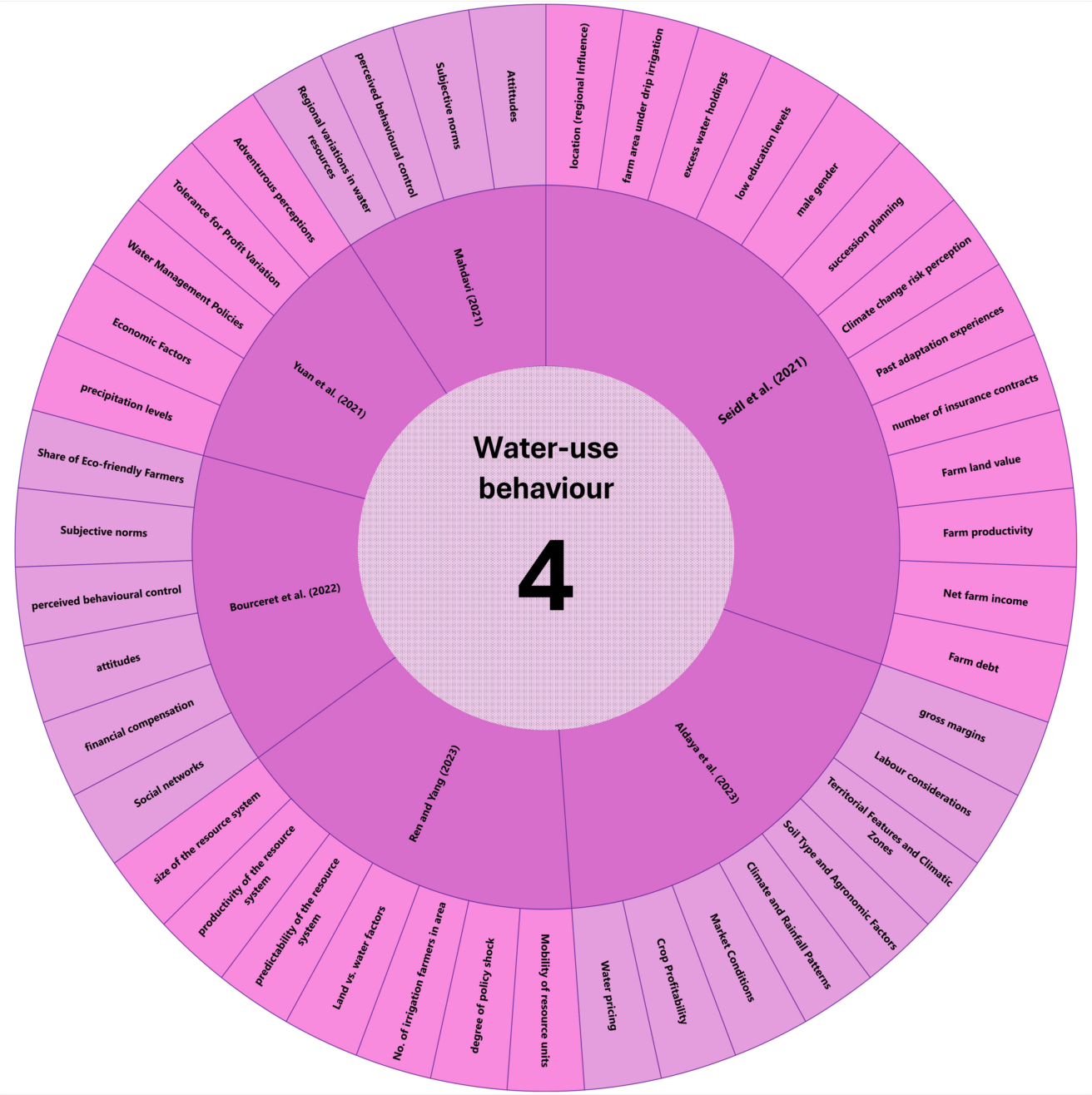


Figure 14. Factors influencing compliance with water-saving policies in agricultural water-use contexts. Source: Authors' compilation. Note: Bourceret et al. [22]; Seidl et al. [24]; Yuan et al. [25]; Ren and Yang [89]; Mahdavi [90]; Aldaya et al. [91].

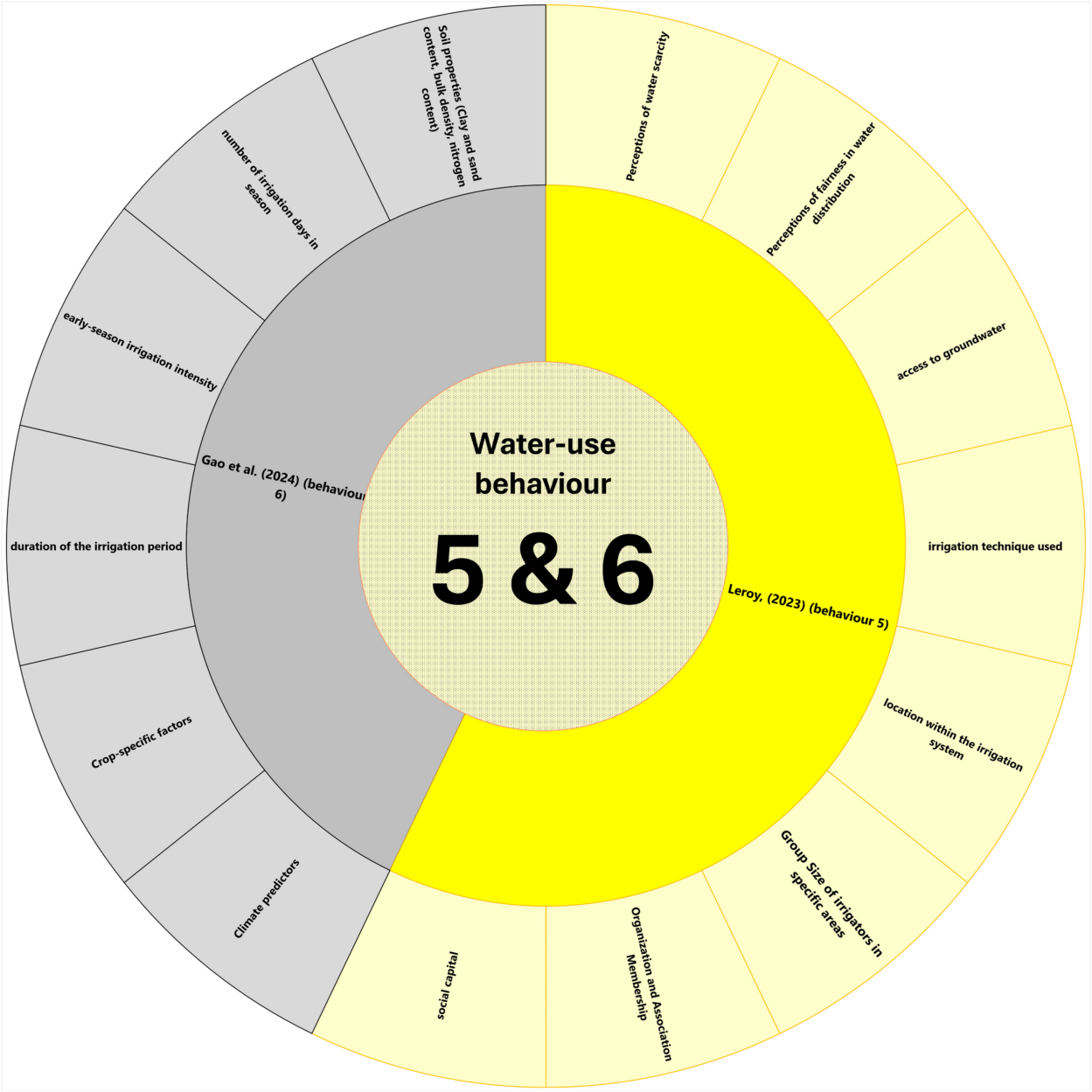


Figure 15. Influential factors in agricultural water-use behaviour in light of institutional performance (water-use behaviour 5) and seasonal irrigation water usage patterns (water-use behaviour 6). Source: Authors' compilation. Note: Leroy [92]; Gao et al. [93].

4. Discussion

In this systematic review, we explored the different water-use behaviours in agricultural settings as reported by the 47 studies included in this review. Our analysis highlighted several key themes and trends in the studies reviewed, providing valuable insights into current practices and areas needing further investigation. Firstly, the geographic distribution of the 47 studies revealed a concentration of research efforts in a few key countries over the past five years. The United States leads with eight studies, which is followed closely by China with seven studies. As highlighted in the introduction, it is clear that understanding behavioural aspects is crucial for achieving water-use efficiency, sustainable agriculture, and broader water resource management goals. However, it is concerning that research efforts directed at understanding water-use behaviour in agricultural contexts over the past five years are concentrated in only a few countries. This geographic distribution of studies is concerning, especially in light of water stress affecting various regions globally, as reported by the Food and Agricultural Organization [94]. The FAO [94] applied the SDG indicator 6.4.2 (this indicator measures the level of water stress and is defined as the ratio of total fresh water withdrawn by all major sectors (agricultural, industrial and municipal) to total renewable freshwater resources, after considering environmental flow requirements) as a measurement of water stress and illustrated that the highest levels of water stress are found in East Asia, western Asia, central Asia, southern Asia, and northern and southern Africa. By not adequately studying water-use behaviour in these countries, we risk hindering progress towards sustainable water management and ultimately lowering the likelihood of achieving SDG 6 before 2030.

Moreover, our results from the word frequency and the keyword co-occurrence network analysis revealed several key themes. The keyword co-occurrence network analysis identified four main clusters, each representing a distinct theme. The first cluster's theme was identified as "Sustainable Agricultural Practices", emphasising the importance of long-term resource availability and minimising environmental impacts through efficient water management in agriculture. This finding is sensible given the extensive attention that sustainable agricultural practices in general have received in the literature [95–99], particularly focusing on sustainable water-management practices [100–103]. Foguesatto et al. [95] highlighted the various potential benefits of adopting sustainable regional and global agricultural practices. However, Foguesatto et al. [95] further mentioned that despite these potential benefits, the adoption rate of these practices remains low in many countries. Considering the points mentioned above might explain why our systematic review revealed sustainable agricultural practices as a prominent theme, since a better understanding of water-use behaviour in the context of sustainable agricultural practices could potentially increase the adoption rate of these practices.

The theme of the second cluster centres around technology adoption for productivity, highlighting the role that technological advancements play in enhancing agricultural productivity, particularly in the context of water management and water-use efficiency. Jararweh et al. [104] argued that given the restricted farming space, water shortages, climate change, and continually changing environmental circumstances, new and novel smart agricultural technologies must be developed. However, according to Levidow et al. [105], while innovative irrigation practices can enhance water efficiency, provide economic advantages, and reduce environmental burdens, farmers do not fully realise these benefits due to various challenges. Barriers include the cost of adopting new technology [104,106], lack of adequate knowledge and data [63,104], and risk of reduced yield [63]. Policies and educational programs are vital to support farmers in overcoming these challenges [107]. Ultimately, integrating advanced technologies into agriculture is crucial to achieving sustainable water management and is seen as an important way to reduce water scarcity [108]. This importance is underscored by our results, which show that 17 of the 47 papers addressed the adoption of water-saving technology as a water-use behaviour, demonstrating an increasing need to understand and promote water-saving technologies in agricultural contexts.

Furthermore, the results of the keyword co-occurrence showed that the theme of the third cluster centres around climate change, adaptation strategies, and water scarcity, particularly concerning agricultural practices. The emergence of climate change adaptation and water scarcity as common themes in our systematic review is sensible, given that agriculture is widely recognised as one of the most vulnerable sectors to climate change [109–112]. According to Mehrazar et al. [113], given the vulnerability of the agriculture sector to climate change, studying the potential impacts of climate change is crucial to ensure food and water security in the future. Moreover, Hanjra and Qureshi [114] highlighted that with increasing population and income growth, there will be a corresponding increase in demand for food and water. Hanjra and Qureshi [114] further mention that irrigation will be the first sector to lose water as water competition by non-agricultural sectors will intensify, which will have implications for food security, hunger, poverty and ecosystem health and services. There is a growing need to develop effective adaptation measures to safeguard agricultural productivity against the adverse effects of climate change and water scarcity. Strategies such as climate-resilient crop varieties [115–117], improved irrigation techniques [117–119], and sustainable water-management practices [112,120] emerge as critical components in mitigating the adverse effects of climate change on water availability and agricultural systems. However, addressing climate change's adverse effects, Srivastav et al. [121] emphasised the importance of following a holistic approach. This aligns with our systematic review's findings, which revealed the multifaceted nature of farmers' adaptation to climate change in water-use-related contexts. Future studies on farmers' adaptive behaviour in water-use-related contexts should consider a holistic approach in modelling their adaptative behaviours.

The fourth cluster identified in our keyword co-occurrence analysis highlighted the theme of modelling and uncertainty in water conservation. The significance of employing models to understand behaviour cannot be overstated. Through behavioural models, researchers gain a better understanding of the complex interplay of factors influencing water usage in agriculture. These models not only serve an academic purpose but are also important to inform policymakers and stakeholders to develop effective water-saving behaviour change strategies [122], efficient resource allocation [123], and effective policy design [124]. It is, therefore, crucial to measure behaviour accurately. According to Reimer et al. [125], it is crucial to consider contextual factors when measuring behaviour, as the variation in these factors can make it difficult to predict and measure farmers' adoption/behaviour. However, our systematic review revealed six water-use behaviours and the various variables influencing these behaviours over the past five years (2020 to 2024). Therefore, our systematic review can be a valid starting point for future studies when modelling behaviour. Additionally, uncertainty emerged as a significant theme in the fourth cluster, underscoring its pivotal role in water management decisions. Dessai and Hulme [126] emphasised that uncertainty is inherently part of decision making in environmental management, influencing the sensitivity of management decisions to uncertainties in environmental predictions. For example, Sun et al. [127] showed that projections of future climate change are plagued with uncertainties, making it difficult for decision-makers to plan adaptation measures. Our keyword co-occurrence analysis results align with the points raised by Dessai and Hulme [126] and Sun et al. [127], as the word "uncertainty" is linked to both "climate change" and "management", suggesting that uncertainty is an issue affecting various aspects of water management in light of climate change. Therefore, when modelling behaviour, it is crucial to account for the influence of uncertain environmental factors on farmers' water-use behaviour.

Furthermore, the findings from our systematic review revealed the multifaceted nature of the variables driving farmers' water-use behaviours in diverse agricultural contexts. Our systematic review identified six water-use behaviours, each with its unique drivers and barriers. However, several overarching themes emerge despite the differences among the six water-use behaviours identified. Firstly, it is clear that a wide range of factors influence farmers' decisions and actions regarding their water usage. Various factors such

as economic considerations, demographic variables, socioeconomic variables, farmers' awareness and perceptions, institutional and policy influences, technical factors, farm and environmental characteristics, psychological and behavioural elements, informational factors and interaction and collaboration among relevant stakeholders are all crucial components. The complex interplay of these various variables in influencing agricultural water-use behaviours highlights the need for comprehensive approaches to water management policies and interventions. The importance of following a comprehensive approach to water management is evident, as highlighted by past initiatives such as the Comprehensive Assessment of Water Management in Agriculture (CA) [128].

Secondly, our results underscore the complexity of water-use behaviours in agricultural settings. It is crucial to acknowledge the limitations of existing behavioural models in capturing this complexity. Academically, the recognition of these complexities in human decision making is evident, with various studies augmenting traditional behavioural models by integrating additional constructs [36,37,39,41]. Our findings provide a significant starting point for future studies aiming to measure water-use behaviour in agricultural contexts. Subsequent research can build upon our findings to determine essential constructs for a more comprehensive understanding.

Lastly, considering that the 47 articles included in our systematic review are from diverse regions globally, it is crucial to recognise that the unique contextual factors of each agricultural setting significantly influence water-use behaviours. Farm characteristics, such as farm size, location and type of crop produced, irrigation complexity, and scale of plantings, interact directly with environmental factors such as the climate, soil quality, and seasonal precipitation patterns. Recognising the contextual interplay is essential for resource efficiency [129], reducing water waste and pollution [130], promoting water sustainability research [131], and designing tailored interventions [132].

5. Conclusions

This systematic review aimed to explore and synthesise the various water-use behaviours in agricultural contexts as reported in the literature from the past five years (2020 to 2024). Our findings provided critical insights, identifying key factors influencing various water-use behaviours in agricultural contexts as well as thematic trends emerging from the 47 studies included in our review. Our review draws several important conclusions about water-use behaviour in agricultural contexts. Firstly, the geographic distribution of the studies showed a significant concentration of research in a few countries over the past five years, notably the United States and China. The concentration of studies in certain countries highlights a geographical gap in research efforts. Addressing this gap is crucial for global progress towards sustainable water management and achieving SDG 6 by 2030. Secondly, our review identified six primary water-use behaviours studied in diverse agricultural settings, which are influenced by a wide range of factors ranging from farm characteristics, economic considerations, and institutional and environmental conditions to psychological and behavioural aspects. The complex interplay of variables found to influence these water-use behaviours highlights the importance of a comprehensive and context-specific approach to promoting sustainable water-management practices in agriculture. Lastly, the themes that emerged from our systematic review highlighted the critical areas of sustainable agricultural practices, technology adoption for productivity, climate change adaptation and water scarcity, and the importance of modelling and addressing uncertainty in water management. These themes underscore the significant progress made in recent years but also highlight persistent challenges.

The implications of our findings extend to policy, emphasising the need for policies that account for the various factors influencing farmers' water-use behaviours. This includes economic incentives, educational programs, and support for technology adoption to enhance water-use efficiency. Furthermore, given the significant influence of regional and environmental factors, water management policies should be tailored to specific agricultural contexts considering local climatic conditions, soil types, and water availability to increase the effectiveness. This includes promoting sustainable agricultural practices to optimise water-use efficiency and minimise environmental impacts. Additionally, facilitating the adoption of innovative water-saving technologies can significantly enhance agricultural productivity while conserving precious water resources. Investing in climate adaptation strategies, such as resilient crop varieties and improved irrigation techniques, is crucial for building resilience to changing climatic conditions and mitigating the impacts of water scarcity. Furthermore, policymakers should prioritise the development of accurate behavioural models to inform decision making and tailor interventions effectively.

In addition, we recommend that governments enhance funding dedicated to teaching farmers about efficient water-use practices and fostering sustainable water-use behaviours. Such efforts are crucial for ensuring sustainable water management and securing water resources for future generations.

Acknowledging certain limitations, the present study followed a systematic procedure to identify keywords and screening sources. However, this process has inherent limitations due to the subjectivity of the authors in selecting and screening studies. Additionally, the reliance on available databases might have excluded relevant studies not indexed in those sources. Language bias is another limitation, as the review included only studies published in English. Moreover, due to financial constraints, we were unable to access three full-text articles, potentially introducing bias by not fully representing all relevant literature.

In conclusion, we recommend that future research focuses on modelling water-use behaviours. Although we identified six water-use behaviours in our systematic review, we will illustrate the application of our findings using one specific behaviour: adaptation to climate change in agricultural water-use contexts (water-use behaviour 1, Figure 11). Our systematic review highlighted that factors such as economic and financial considerations, institutional and information access, farm characteristics and resources, sociodemographic factors, and perceptions and experiences influence farmers' adaptation to climate change.

We have augmented the theory of planned behaviour (TPB) with these categories to show how these influencing variables can be integrated into standard behavioural models such as the TPB. The TPB was chosen for illustration purposes due to its widespread use in understanding human behaviour, which is supported by extensive empirical evidence across various fields in the literature. Figure 16 depicts the augmented adaptation to climate change TPB model. By integrating insights from our systematic review, researchers can develop more tailored models to better understand and predict water-use behaviour in diverse agricultural contexts. While Figure 16 focuses on the variables influencing climate change adaptation in water-related contexts identified in this systematic review, it is still important for future studies to consider the contextual setting of their specific research.

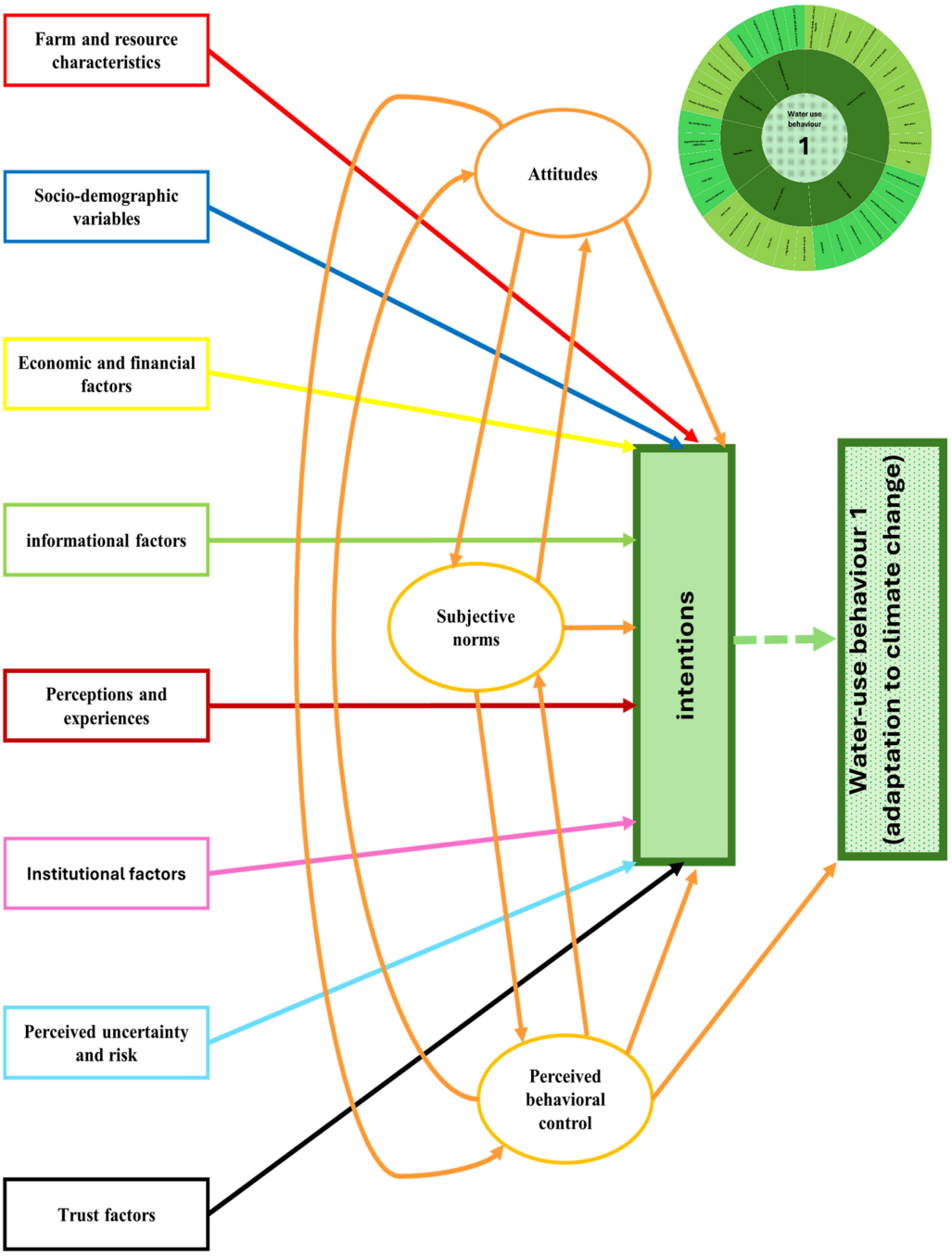


Figure 16. Augmented theory of planned behaviour (TPB) model for adaptation to climate change in agricultural water-use contexts. Source: Authors' compilation.

Author Contributions: M.A.M.: conceptualisation, software, validation, analysis, and writing the first draft of the manuscript. Y.T.B.: resources, funding, project administrator and collaborated with M.A.M. as a main supervisor of his Ph.D. and writing the final draft. H.J.: a co-promoter of M.A.M. and he aided with the final writing of the paper. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement: This paper is based on the literature review; all the reviewed papers will be available on reasonable request from correspondence author, M.A.M.

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Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

Table A1. Quality assessment of studies.

Study	Reference Number	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Final Score
Wang et al. (2021)	[62]									6.5
Mahdavi (2021)	[90]									7.5
Muenratch and Nguyen (2023)	[75]									7.5
Wang et al. (2023)	[41]									7.5
Mi et al. (2021)	[63]									7.5
Alauddin et al. (2020)	[76]									7
Berthold et al. (2021)	[64]									6
Hoang-Thi et al. (2023)	[77]									6
Xiuling et al. (2023)	[65]									7
Ortiz et al. (2023)	[78]									7
Fan and McCann (2020)	[66]									6
Momenpour et al. (2021)	[79]									7
Johnson et al. (2023)	[80]									8
Bailey et al. (2021)	[67]									6.5
Yuan et al. (2021)	[25]									7
Irmak et al. (2022)	[81]									7
Bogdan and Kulshreshtha (2021)	[82]									6.5
Cavazza et al. (2022)	[68]									5
Salas-Zapata et al. (2023)	[83]									4
Dessalegn et al. (2022)	[26]									6
Sabzevar et al. (2021)	[27]									5.5
Usman et al. (2023)	[58]									7.5
Rafii (2022)	[84]									5
Woldeselassie et al. (2021)	[56]									6
Michalak (2020)	[57]									5
Roberts et al. (2022)	[69]									4.5
Sajid et al. (2022)	[70]									6.5
Alotaibi and Kassem (2021)	[20]									7.5
Reints et al. (2020)	[71]									7.5
Bourceret et al. (2022)	[22]									8
Velasco-Muñoz et al. (2022)	[85]									5
Davenport et al. (2022)	[59]									7.5
Sabbagh and Gutierrez (2023)	[28]									7.5
Ataei et al. (2022)	[21]									6.5
Seidl et al. (2021)	[24]									8
Mekonnen et al. (2022)	[74]									6
Fischer and Sanderson (2022)	[86]									5.5
Wheeler et al. (2021)	[60]									7
Asthana (2022)	[87]									5
Abebe et al. (2022)	[61]									8
Leroy, (2023)	[92]									7
Danso et al. (2021)	[72]									6
Gao et al. (2024)	[93]									8
Ricart and Rico-Amorós (2021)	[88]									7.5

Table A1. *Cont.*

Study	Reference Number	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Final Score
Aldaya et al. (2023)	[91]									7.5
Ren and Yang (2023)	[89]									7.5
Cui et al. (2022)	[68]									8

Note: the colour-coded system entails the following: green (fully met criterion = 1 point); yellow (partially fulfilled criterion = 0.5 points); red (criterion not met = 0 points); and final scores were calculated by summing points across all criteria for each study. Studies with a final score lower than 4 out of 8 were excluded. Source: Authors' compilation.

Table A2. Characteristics of included studies (n = 47).

	Reference Number	Country of Study	The Type of Water-Use Behaviour Investigated	Key Findings (Factors Influencing Water-Use Behaviour)
Wang et al. (2021)	[62]	China	Farmers' adoption of water-saving technologies (WST)	The findings suggest that education, access to extension services, and participation in off-farm work are crucial in encouraging farmers to adopt WST sustainably. Additionally, the study highlights the importance of addressing water scarcity and the need to focus on cooperative organisations and irrigation cost management in promoting the adoption of WST.
Mahdavi (2021)	[90]	Iran	Farmers' intentions to comply with water-saving policies	The study found that attitudes, subjective norms, and perceived behavioural control significantly affect farmers' intentions to comply with water policy options. The study area was divided into four regions based on water resources, and the intention to comply with water policy options varied across these regions. The study also highlighted the importance of understanding farmers' incentives to adapt to water-saving policies for the success of government intervention.
Muenratch and Nguyen (2023)	[75]	Thailand	Farmers' intention towards groundwater-saving behaviour	The results showed that groundwater knowledge, awareness of extraction impacts, and groundwater tariffs influence agricultural water users' saving behaviour. Intentional saving behaviour is further shaped by subjective norms and perceived behavioural control with social pressures and individual capability playing significant roles. Enhancing groundwater awareness and knowledge and implementing tariffs can aid in controlling abstraction and promoting water-saving behaviour.
Wang et al. (2023)	[41]	China	Farmers' adoption intentions of water-saving agriculture (WSA)	The study results revealed that subjective norm is the most crucial factor influencing farmers' adoption intention, which is followed by perceived behavioural control and attitude. Awareness of environmental consequences positively affects subjective norms and attitudes, while perceived ease of use improves perceived behavioural control. In addition, farmers who participated in WSA training showed higher adoption intentions compared to their counterparts who did not attend any training.
Mi et al. (2021)	[63]	China	Farmers adaptation to arid climates, specifically in terms of waiting times to adopt water-saving technologies (WST)	Farmers' adoption of water-saving technologies is influenced by capital endowments, the scale of cotton planting, neighbours' adoption decisions, policy subsidies, and cooperative membership. Land transfer optimises resource allocation, while human capital factors like health, education, and labour influence adoption. Farmers with more labourers are less willing to adopt technologies and have longer wait times. Household income affects waiting times but does not significantly affect adoption willingness. Cooperatives can shorten waiting times by reducing costs and providing subsidies. Government subsidies positively impact adoption willingness but negatively affect decisions and waiting times.
Alauddin et al. (2020)	[76]	Bangladesh	Farmers' adoption of alternate wetting and drying (AWD) irrigation as a water-saving technology	The age and education level of the household head, access to prior weather information, landownership, topography, and soil type are significant determinants of AWD adoption. Younger, less-educated farmers are more inclined to adopt AWD, while access to weather information tends to discourage adoption. Furthermore, farmers with higher amounts of irrigated land, high-elevation land, and clay-type soil are also more likely to adopt AWD. AWD adopters irrigate less frequently, resulting in cost savings and yield improvements. To encourage widespread adoption, policies should prioritise information dissemination, farmer training, subsidies, and institutional support strengthening.

Table A2. *Cont.*

	Reference Number	Country of Study	The Type of Water-Use Behaviour Investigated	Key Findings (Factors Influencing Water-Use Behaviour)
Berthold et al. (2021)	[64]	The U.S	Farmers' adoption of irrigation-scheduling tools	Significant barriers to adoption identified include lack of access to reliable weather data, uncertainty about future water availability, cost-effectiveness of technologies, and risk of reduced yield. Factors influencing growers' decision to adopt irrigation scheduling tools include maintaining land quality, increasing water-use efficiency, and improving water availability for future generations. Age, education level, and years of agricultural experience impact growers' knowledge and adoption of irrigation-scheduling methods.
Hoang-Thi et al. (2023)	[77]	Vietnam	Farmers' adoption behaviour of water conservation	Intrinsic factors like perception of climate change, income, assets, age, and education positively influence households' adoption of water conservation strategies. Households that perceive higher risks from climate change are more likely to conserve water. Extrinsic factors like access to credit, rainfall, cooperation, and extension also impact water conservation adoption. Households with access to credit and those in areas with higher rainfall were less likely to conserve water. The strongest predictors of households' water-conservation behaviour were perceptions of climate change risks and impacts on income. Education and extension programs can help improve awareness and adoption of water conservation strategies.
Xiuling et al. (2023)	[65]	China	Farmers' adoption of water-saving irrigation technology (WSIT)	The results show that risk aversion negatively impacts farmers' adoption of water-saving irrigation technology, while online and offline technical training has a positive effect. Technical training can alleviate the inhibitory effect of risk aversion on farmers' adoption of water-saving irrigation technology. The impact of risk aversion, technical training and their interaction differ across farmers of different ages, education levels, and farm sizes.
Ortiz et al. (2023)	[78]	Ecuador	Farmers' willingness to adopt water conservation practices	The results show that farmers have a positive attitude towards willingness to pay for solid rain irrigation technology and training for conflict resolution and cooperation. However, they were not interested in manure composting or municipal solid waste management. Although solid rain is not yet well known in the study area, farmers with larger farms displayed a strong interest in experimenting with solid rain. The willingness to pay for the conservation practices does not cover their total implementation costs, so the researchers suggest cost-sharing schemes to promote adoption. The study considered economic feasibility when selecting attributes related to improved irrigation systems, manure management, and water governance, indicating that financial considerations play a role in adoption decisions.
Fan and McCann (2020)	[66]	The U.S.	Farmers' adoption of pressure irrigation systems (PIS) and scientific scheduling practices (SIS)	Perceived barriers, information sources, farm characteristics, water sources, costs, and climate variability influence the adoption of pressure irrigation and scientific scheduling practices. Federal assistance boosts adoption with larger farms more likely to adopt pressure irrigation systems. State-level factors account for more variation in pressure irrigation adoption, while farm-level factors account for more variation in scientific scheduling adoption. Significant barriers to adoption include benefits not covering costs and time constraints. Compared to planting only corn, farmers who planted only soybeans are less likely to adopt SIS, while those who planted both crops are likelier to adopt SIS. Larger farming areas and a more significant percentage of owned land positively affect SIS adoption. Technical and financial assistance for irrigation and drainage improvements, along with information from extension agents, private irrigation specialists, irrigation equipment dealers, government specialists, media reports, and electronic information services, have been found to positively impact the adoption of SIS.
Momenpour et al. (2021)	[79]	Iran	Farmers' water-conservation behaviours (WCBs)	Seven factors influenced farmers' water conservation behaviour (WCBs): institutional, economic, natural, extensional, social, attitudinal, and self-identity. Economic factors, such as input costs and crop insurance, had the largest impact on WCBs. Extension services from agricultural organisations, government policies, and natural conditions like drought, climate change, and soil salinity also impacted farmers' WCBs. These factors accounted for 47.5% of the variance in WCBs.

Table A2. *Cont.*

	Reference Number	Country of Study	The Type of Water-Use Behaviour Investigated	Key Findings (Factors Influencing Water-Use Behaviour)
Johnson et al. (2023)	[80]	Burkina Faso (West Africa)	Farmers' perception of water scarcity and their adoption of key adaption strategies	Farmers used various adaptation strategies to manage water scarcity, including conservation practices like field bunding and crop rotation. Climate, soil type, farming association membership, gender, and irrigation water availability influenced these choices. The study also found that farmers' perception of water scarcity frequency negatively influenced their use of more irrigation water from the scheme. Water availability from the irrigation scheme in the dry season was a key factor. Farmers who perceived water availability as restricted were less likely to adopt specific strategies.
Bailey et al. (2021)	[67]	The U.S.	Farmers' adoption and allocation of irrigation techniques	Irrigation practices are influenced by peer networks and relationships, with producers being more likely to adopt technologies used by their peers. Information sharing and positive results also influence adoption. Location and participation in conservation programs can modify the effect of peer influence on technology adoption. Involvement in a regional conservation partnership program can alter the impact of peer networks on the producer's decision regarding irrigation techniques. Field management practices and water flow control technologies can have complementary or substitute relationships based on peer effects. Physical farm characteristics, education levels, and crop choices also impact a producer's decision to use certain irrigation practices. Peer influence tends to have the strongest effect. The findings further show that the use of tail-water recovery systems increases the likelihood of farmers adopting end-block irrigation by 17.8%. The findings show that participation in regional conservation partnership programs modifies how peer influence affects irrigation practices. Regarding yield expectations, the study found that higher expected yields of corn slightly increase the likelihood of using end-block irrigation. The findings also revealed that seasonal precipitation increases the likelihood of using certain irrigation practices. Farmers are likely to adjust their irrigation practices based on the actual availability of water from rainfall.
Yuan et al. (2021)	[25]	China	The effects of farmers' behavioural characteristics on crop choices and water use in light of water management policies	The results show that farmers with adventurous perceptions and high tolerance tend to choose high-profit crops and use more water. In contrast, farmers with cautious perceptions and low tolerance prefer stable profit crops and use less water. The two types of farmers also exhibit different responses to water management policies. Farmers with adventurous behaviour are more sensitive to policy changes. The effects of farmers' behavioural characteristics vary across various locations and scales. The study also found that perception of uncertainty (regarding future crop prices, planting costs, and precipitation) influences water-use behaviour. The study showed that historical and expected future crop prices impact farmers' decisions on which crops to plant, influencing water use. The study found that precipitation levels affect irrigation needs and influence water-use behaviour and crop choices.
Irmak et al. (2022)	[81]	The U.S.	Farmers' irrigation practices and decisions (timing and amount of water applied)	The results suggest that irrigation decisions are not based on scientific data and protocols but are driven more by crop conditions, soil feel, personal schedules and neighbour practices. Substantial variability was found between fields regarding initiation, duration, and termination of irrigation season, irrigation frequency, and depth applied. The study found that different irrigation methods (centre pivot, gravity, subsurface drip) significantly influence water withdrawal and application patterns. The study found that initiating and terminating irrigation (starting 40–70 days after planting and ending 120–140 days after planting) are critical in determining water-use behaviour. The study found that peak water abstraction occurs during July and August, indicating a seasonal influence on water-use behaviour. The study also found that site-specific factors such as precipitation, soil moisture, and evaporative demand significantly impact irrigation requirements and water-use behaviour. In addition, the study showed that water allocation moratoriums influence irrigation practices and compliance with allocated water depths, thus affecting water-use behaviour.

Table A2. *Cont.*

	Reference Number	Country of Study	The Type of Water-Use Behaviour Investigated	Key Findings (Factors Influencing Water-Use Behaviour)
Bogdan and Kulshreshtha (2021)	[82]	Canada	Farmers' adoption of improved water-management practices and technologies in response to climate change challenges	Growers interested in adopting beneficial management practices (BMPs) had less farming experience, diverse farming goals, higher educational attainment, and a higher degree of specialisation in tomato, cranberry, or onion production. While most growers perceived BMPs as profitable and able to reduce water use and improve yields, critical barriers to adoption included the initial investment cost, market stability, low fruit or vegetable prices, and low profit margins.
Cavazza et al. (2022)	[68]	Italy	The adoption of Information and Communication Technology (ICT) and its impact on water demand, water use, and water productivity at the district level	The results show that ambiguity can limit ICT implementation and hinder water savings. However, familiarity can eventually lead to coordinated actions and efficient ICT-aided irrigation. The authors recommend uncertainty-management policies to reduce ambiguity and increase familiarity with new ICTs. The study found that ICT's perceived benefits and expected utility strongly influence decision-makers' adoption decisions. Decision-makers who see clear advantages, such as increased efficiency and productivity, are likelier to adopt ICT. The study found that economic incentives and supportive policies significantly influence the adoption of ICT for irrigation management. Subsidies, financial incentives, and favourable policies can reduce the economic barriers to adoption, making it more feasible for decision-makers to invest in new technologies.
Salas-Zapata et al. (2023)	[83]	Colombia	The water management of farm workers concerning their knowledge, attitudes, and practices (KAP)	The workers showed a satisfactory level of knowledge and attitude and an excellent level of practice regarding water management. However, no relationship was found between the workers' practices and their knowledge and attitude. The workers' practices seemed to be influenced more by the organisational environment and rules rather than their own KAP. The results suggest that workers' practices do not depend on their knowledge and attitude, as they are workers employed by one company. It is possible that their practices reflect the organisational norms rather than their knowledge and attitude. In addition, farm activity, home location, and farm location showed statistically significant relationships with the workers' practices. Educational level, sex, and years of experience also correlated with certain aspects of the workers' water-management behaviour.
Dessalegn et al. (2022)	[26]	Egypt	Farmers' adaptive water-management practices	Farmers' choices of adaptive water-management practices were influenced by individual changes at the micro-, meso- and macro-levels and their interactions. The study demonstrated that gender-based constraints at the meso-level and gender-sensitive micro-level influences significantly shaped farmers' water-management behaviours. The study found that farmers in the Nile Delta region of Egypt exhibited gender-differential water management choices influenced by various biophysical and socioeconomic factors. The study showed that water availability, quality, and access were key factors in farmers' adaptive water-management practices, with the Ministry of Water Resources and Irrigation's water releases impacting their decisions. Adaptation choices were more sustainable when supported by enabling environments like local regulations, national institutions, policies, and global trends like climate change and markets. Farmers' gender-differential water management choices were influenced by individual drivers and their interactions across different levels. Policy changes encouraging sustainable resource use, building institutional capacity, private sector engagement with monitoring, and market forecasts can improve farmers' adaptation strategies.
Sabzevar et al. (2021)	[27]	Iran	Farmers' adaptation strategies to water scarcity conditions	Farmers' adaptation strategies are influenced by various factors such as knowledge, attitude, perception, concerns, self-efficiency, social capital, access to information, and risk taking. Knowledge positively impacts technical skills, self-efficiency influences risk taking and adaptation strategies, and perceptions and socioeconomic variables influence decisions. Risk taking and perception of water scarcity are effective adaptation strategies. Increased knowledge and awareness can help farmers make optimal decisions. Agricultural extension and education can improve technical skills and self-efficiency, promoting adaptation strategies. Improving extension activities and training courses is recommended.

Table A2. *Cont.*

	Reference Number	Country of Study	The Type of Water-Use Behaviour Investigated	Key Findings (Factors Influencing Water-Use Behaviour)
Usman et al. (2023)	[58]	Pakistan	Farmers' perceived impact of climate change on irrigation water and the adoption of adaptation measures to mitigate its adverse effects	Farmers use various adaptation strategies like water harvesting, crop diversification, increased irrigation, laser land levelling, ridges, water-harvesting schemes, changing irrigation time, high-efficiency irrigation systems, and water-saving technologies. Factors like age, farming experience, education, household size, land area, tenancy status, credit access, weather information, soil quality, tube well ownership, remittances, extension services, and information on climatic risks influence the adaptation strategies. These findings suggest that various socioeconomic, demographic, and agronomic factors are crucial in influencing farmers' decisions regarding adopting adaptation strategies for irrigation water management in response to climate change.
Rafii (2022)	[84]	Indonesia	Farmers' adoption of incremental adaptation techniques for agricultural water management	Farmers' psychological factors, including concern, perceptions, and knowledge, significantly influence their adoption of incremental adaptation strategies and management of agricultural water resources. Worry and knowledge are more influential than perceptions. Self-efficacy and technical skills also impact farmers' use of these strategies. Higher self-efficacy and technical skills strengthen the impact of psychological factors. Farmers concerned about water scarcity and aware of alternative strategies are more likely to use incremental adaptation techniques. Positive attitudes and knowledge also help farmers manage limited water supplies effectively. Farmers' technical skills, including their ability to employ incremental techniques, positively influence their agricultural water-management practices, contributing to maximising the benefits of water resource management.
Woldeselassie et al. (2021)	[56]	Ethiopia	Water-use behaviour of potato farmers in response to climate change-induced moisture stress	The study revealed that most farmers determined irrigation intervals based on soil moisture content, while some based it on pumping cost. Constraints in the use of irrigation water for potato production were identified, with the high cost of fuel for pumping water, scarcity of irrigation water, and low availability of drought-tolerant potato varieties being the most significant factors influencing water-use behaviour. The study found that farmers timed their irrigation practices to avoid the day's hottest hours, thus minimising water loss through evapotranspiration. It was also found that experience-based methods to estimate soil moisture content guided irrigation intervals. The study found that the need for supplemental irrigation arose due to the potato crop's coarse and shallow root system, making water and mineral uptake inefficient. Farmers had to bridge the moisture gap during the main rainy season.
Michalak (2020)	[57]	Poland	How different entities and farms manage water resources in response to climate change	Larger enterprises (with over 250 employees) were more likely to use irrigation techniques and physical adaptation measures than smaller enterprises. For instance, 50% of large enterprises used irrigation techniques compared to 24.1% of micro-enterprises. The level of access to systematic and reliable information on climate change impacts influenced how entities adapted their water-management practices. Only 17% of respondents had easy access to such information, which affected their ability to implement effective adaptation measures. Different crops require different water-management practices. For example, irrigation systems were commonly used for fibrous plants and fruit trees, while drought-resistant and water-saving crops were prevalent among cereals, legumes, and oil plants. In the study, it became evident that the capacity of Polish farmers to address the challenges posed by climate change on water management is heavily influenced by their financial resources. Micro-farms and small farms, which may have limited financial resources, face greater challenges in adopting such measures.

Table A2. *Cont.*

	Reference Number	Country of Study	The Type of Water-Use Behaviour Investigated	Key Findings (Factors Influencing Water-Use Behaviour)
Roberts et al. (2022)	[69]	The U.S	Farmers' perceptions and adoption of water-saving practices	The study indicates that outreach efforts, funding, and research have successfully influenced producers to make more water-wise management decisions, but there is still room for improvement in some areas. The surveys from 2012 and 2014 show that producers' perceptions of these water-saving practices have become more favourable over time, which is likely due to education and extension efforts. Extension personnel's promotion of flow meters and CHS programs significantly influenced producers' perceptions and adoption rates of these technologies. The use of flow meters for measuring irrigation water increased significantly between 2012 and 2014 as producers recognised them as the best method. However, some producers still had concerns that meters could lead to taxes or fees on water use. Shortening furrow run distances can reduce water usage and improve irrigation efficiency, making this practice appealing to some producers. Shortened furrows can lead to more uniform water application, reducing deep percolation at the top of the field and excessive runoff at the bottom. The potentially high costs associated with re-levelling fields, creating extra ditches, and purchasing additional equipment can deter producers from adopting shorter furrow runs.
Sajid et al. (2022)	[70]	Pakistan	Farmers' practices and challenges related to irrigation water provisions include limited water allocation, over-irrigation, and barriers to adopting new irrigation technologies and methods	Farmers, officials, and academicians reported limited water allocation as the main problem in the canal water distribution system. Farmers practised over-irrigation and lacked awareness of soil moisture and crop water requirements. The key barriers to adopting interventions like soil moisture sensors, on-farm water storage, and drip irrigation were low awareness, lack of training, and financial constraints. Farmers' education was positively correlated with awareness of sensors and storage facilities, while larger farmholders were willing to conduct joint experiments. Farmers' reliance on tube-well water and exchanging Warabandi canal water with neighbours are barriers to adopting water storage facilities.
Alotaibi and Kassem (2021)	[20]	Saudi Arabia	Farmers' adoption of sustainable water-management practices	There was a positive association between adopting sustainable water-management practices and awareness regarding water pollution caused by agriculture. Farmers with more awareness showed a higher adoption of practices. Interestingly, the study found that the type of crops cultivated by farmers negatively and significantly affected the adoption of SWM practices. Farmers specialising in cultivating palm trees were likelier to adopt SWM practices than those cultivating various crops. Surprisingly, the study did not find a significant effect of extension contact on adopting SWM practices. This suggests that agricultural extension services in Saudi Arabia may not effectively promote SWM practices.
Reints et al. (2020)	[71]	The U.S	Farmers' adoption of water-efficient technologies and management practices	The study identifies four bundles of technologies and practices for improving water management in avocado growers. Factors such as farm location, income from avocados, cooperative extension advice, and farmer characteristics influence the adoption of these technologies. Growers in arid regions with higher incomes are likelier to adopt technologies, while younger growers tend to adopt more sophisticated bundles. Cooperative extension plays a crucial role in promoting adoption through information and recommendations. The complexity of irrigation systems negatively affects the probability of adoption. Growers with more complicated irrigation systems are less likely to adopt water-efficient practices.

Table A2. *Cont.*

	Reference Number	Country of Study	The Type of Water-Use Behaviour Investigated	Key Findings (Factors Influencing Water-Use Behaviour)
Bourceret et al. (2022)	[22]	France	The study explores the interplay between farmers' behaviour, policy measures, agricultural practices, and water pollution levels in drinking water catchments	The study found that behavioural characteristics strongly influence the adoption of low-input farming practices and the concentration of pollutants in water. Specifically, factors like subjective norms, attitudes, and perceived behavioural control (PBC) affect the adoption of these practices. The presence of eco-friendly farmers, who have a favourable attitude towards low-input farming practices, improved the effectiveness of protection programs. Tailoring policies to the specific farmer population by accounting for their behavioural characteristics can improve policy outcomes. The study noted that when farmer characteristics are unknown, mixes of policy measures combining financial incentives and training, though costly, may be more effective. The level of monetary compensation positively affects adoption, and it influences the adoption of voluntary water pollution reduction technologies. The study also found that the level of training intensity included in the protection program positively affected the final share of low-input farmers. Specifically, higher-intensity training was associated with increased adoption of low-input farming practices. The study also found that social networks significantly impacted the adoption of these practices, suggesting that farmers were influenced by the behaviour and attitudes of their peers within their social networks.
Velasco-Muñoz et al. (2022)	[85]	Spain	The adoption of sustainable water-management practices among key stakeholders (farmers, policymakers, and researchers)	The main barriers to adopting sustainable water-management practices are costs, farm characteristics, lack of research, and cultural aspects. Factors that promote the adoption of sustainable water-management practices include technology accessibility, social networks, and political incentives.
Davenport et al. (2022)	[59]	The U.S	Drought risk perceptions and future irrigation behaviours among farmers	The study found that farmers who believed future droughts were likely in their local area tended to have a higher likelihood of adopting or expanding irrigation systems. According to the study, farmers who perceived their farm operations as vulnerable to drought-related impacts were likelier to perceive drought as a significant risk. The study found that farmers' perceptions of drought risk, influenced by future exposure belief and farm sensitivity appraisal, significantly affected their likelihood of adopting or expanding irrigation systems. Anticipated changes in climate conditions, such as increased variability in water supply during the growing season, also influence farmers' perceptions of drought risk and subsequent irrigation behaviours.
Sabbagh and Gutierrez (2023)	[28]	Lebanon	Farmers;' adoption of micro-irrigation systems	The study found that effort expectancy influences the behaviour adoption of micro-irrigation systems by making the technology seem more straightforward to use, thus increasing the intention to adopt it. In addition, performance expectancy was found to influence the behaviour adoption of micro-irrigation systems by affecting farmers' beliefs about the benefits and efficiency of the technology. Facilitating conditions were also found to influence the behaviour adoption of micro-irrigation systems by providing the necessary support and infrastructure, thus making it easier for farmers to implement the technology. Experienced farmers are more likely to accept and use micro-irrigation than inexperienced farmers, indicating that prior experience influences the adoption of water-saving technologies. Age moderates the adoption of micro-irrigation systems among potato farmers with younger farmers finding it more challenging to persuade older generations to embrace new technologies.

Table A2. *Cont.*

	Reference Number	Country of Study	The Type of Water-Use Behaviour Investigated	Key Findings (Factors Influencing Water-Use Behaviour)
Ataei et al. (2022)	[21]	Iran	Farmers' water-conservation behaviours	The study found that farmers' intention for water conservation significantly influences their water conservation behaviour. Furthermore, the study found that personal norms influence farmers' water conservation intention positively and significantly, suggesting that when farmers feel a moral obligation towards conserving water, their intention to conserve water increases. Social norms were found to positively and significantly influence farmers' water conservation intention, highlighting that the social pressures and expectations from peers, family, and community members play a crucial role in shaping farmers' intentions to conserve water. Furthermore, awareness of consequences positively and significantly influences farmers' personal norms, showing that farmers who are aware of the negative consequences of not conserving water develop stronger personal norms towards water conservation. Subjective constraints, driven by farmers' perceptions of their abilities, significantly impact their water conservation intentions and behaviours. Meanwhile, objective constraints, encompassing external factors like resource availability and environmental conditions, also play a crucial role in shaping farmers' intentions and behaviours towards water conservation. The study further found that farmers' attitude towards water conservation significantly influences their intention to conserve water. The study also found that habitual processes are influenced by both subjective constraints and objective constraints, suggesting that routine behaviours and habits related to water conservation are formed and reinforced by both internal perceptions of ability and the external availability of resources.
Seidl et al. (2021)	[24]	Australia	Farmers' future irrigation adaptation strategies to uncertainty due to climate change, water scarcity, and economic pressure. Three adaption strategies were considered: (1) expansive adaption, (2) accommodating adaption, and (3) contractive adaption	The study found that farm debt positively influences planned expansive and contractive adaptation, though this effect diminishes as debt levels increase. In addition, net farm income was also found to influence accommodating adaption strategies significantly. Farm productivity was found to influence planned expansion adaption while negatively influencing the adaption of planned contractive strategies. Farmland value showed a strongly statistically negative impact on planned accommodating adaption. In addition, the number of insurance contracts positively influences planned expansive and accommodating adaption. From a human and social capital perspective, past adaptation experiences influenced all three adaptation strategies. Climate change risk perception influences both planned expansive and accommodating adaptation positively. The study further found that succession planning influences planned expansive and accommodating adaptation positively but planned contractive adaptation negatively. Male gender was found to be a significant positive driver for planned expansive adaption positively. Low education levels were found to influence planned contractive adaptation positively. From a natural and physical capital perspective, the study showed that excess water holdings negatively influence planned expansive adaptation and contractive adaptation positively. Furthermore, it was found that large farm areas under drip irrigation influenced planned expansive adaptation negatively. The results also highlighted the negative influence of location in Victoria or South Australia on planned contractive adaptation, which suggests that irrigators in these regions are less likely to plan reductions in irrigation.
Mekonnen et al. (2022)	[74]	Ethiopia	The influence of social ties on information exchange among farmers regarding on-farm water-management practices	Friendship and field proximity were key determinants of information flow between technology and information recipients, while relatives or neighbours played a minor role. Productive friendships, as indicated by knowing each other's input decisions and production levels, facilitated more information exchange. Farmers who had plots next to each other or usually passed by each other's plots were more likely to exchange information on irrigation practices. Technology recipients who usually passed by the plots of information recipients were more likely to provide information. In contrast, information recipients with plots next to technology recipients were likelier to receive information. Shared knowledge of farming practices, including the size of irrigated plots and the seed variety used, facilitated information exchange on the recommended duration of irrigation events. Ad hoc pairs formed during the project did not significantly impact information flow beyond the effects of friendship and field proximity.

Table A2. *Cont.*

	Reference Number	Country of Study	The Type of Water-Use Behaviour Investigated	Key Findings (Factors Influencing Water-Use Behaviour)
Fischer and Sanderson (2022)	[86]	The U.S	How the physical water environment influences farmers' water conservation behaviour	The study results showed that the physical water context matters and influences water conservation norms both directly and indirectly through worldviews, beliefs, and values. Farmers in wetter contexts hold stronger water conservation norms, while those in more arid contexts hold weaker norms. The physical water context for irrigators shapes their worldviews, influencing their climate change beliefs and water conservation norms. For dryland farmers, the physical water context has a more direct influence on water conservation norms. Values are the strongest explanation of water conservation norms for both groups with environmental values having the strongest effect. Stronger environmental (biospheric) values, traditional values, and openness values were associated with stronger water conservation norms among irrigators. Conversely, holding self-interest values was associated with weaker norms.
Wheeler et al. (2021)	[60]	Australia	Farmers' climate change risk perceptions and farm adaptation behaviour	Farmers with higher debt and a larger share of permanent crops in areas with higher temperatures and less rainfall were likelier to believe climate change posed a risk. There was evidence of a feedback loop where farmers who initially believed climate change was a risk took actions to reduce their risk exposure, which negatively fed back on their climate change concern. Conversely, original deniers who increased their risk exposure became more concerned about climate change. Farmers who sold land, decreased their irrigated area, and sold water entitlements were likelier to change from believers to deniers/unsure, suggesting reduced risk exposure lessened climate change concern. At the same time, deniers who increased irrigated areas and bought water entitlements became more concerned about climate change risk. Farmers engaged primarily in permanent cropping (e.g., grapes or fruit trees) were less likely to perceive climate change as a risk than those primarily involved in annual cropping. This suggests that the crop type influenced water-management practices and risk perceptions. Deniers (farmers who did not perceive climate change as a risk) had larger average farm sizes than the rest of the sampled population. This may indicate differences in water utilisation practices and resource management strategies based on farm size. Believers (farmers who perceived climate change as a risk) had a statistically significantly larger irrigated area than all other farmers. Believers had statistically significantly higher debt-to-equity ratios, while deniers had statistically significantly lower debt-to-equity ratios. This suggests that financial factors may influence farmers' decisions regarding water management and risk perceptions related to climate change.
Asthana (2022)	[87]	Cambodia	How psychological factors like mindfulness and environmental concern influence irrigators' conservation decision making	The study highlights the potential role of environmental concern as a mediator between mindfulness and irrigation water conservation. Mindfulness has a direct effect on increasing physical irrigation efficiency. In addition, mindfulness also has an indirect effect on increasing physical irrigation efficiency through environmental concerns. Environmental concern plays a mediating role in the relationship between mindfulness and physical irrigation efficiency. The estimated impact of mindfulness through environmental concern is about two thirds of the total effect with the remaining one third coming directly from mindfulness.
Abebe et al. (2022)	[61]	South Africa	Farmers' planned and actual adaptation to cope with the effects of climate change	A wide range of factors were found to influence farmers' adaptation decisions, including education, age, gender, land size, income, credit access, climate perceptions, and past adaptation experiences. Education, access to transportation, and credit were found to increase the likelihood of farmers planning expansionary adaptation practices. Meanwhile, age, off-farm income, and climate change perceptions decreased the likelihood. Differences were found between factors influencing planned versus actual adaptation practices. For example, past adaptation experience positively influenced planned adaptation but did not significantly impact actual adaptation. Factors such as land size and livestock holdings also influenced adaptation practices. Larger farms may have more complex irrigation systems, and livestock management practices can affect water availability and quality. Obtaining information from extension officers positively impacted both planned and actual adaptation practices. Extension services likely provide guidance on water-efficient farming methods. In addition, the study showed that previous adaptation experiences positively influenced planned and actual adaptation practices.

Table A2. *Cont.*

	Reference Number	Country of Study	The Type of Water-Use Behaviour Investigated	Key Findings (Factors Influencing Water-Use Behaviour)
Leroy (2023)	[92]	Mexico	The influence of community-based water management institutions on irrigators' water-management behaviour	The results show significant differences in the institutional performance of irrigation management between the four ejidos studied, which can be explained by biophysical factors (irrigation technique, access to groundwater, and location) and community characteristics (social capital and group size). The level of social capital within an ejido, including social ties, trust in other farmers, and participation in collective activities, significantly influences water-management practices and compliance with irrigation rules. Farmers' membership in local associations or producer groups affects their water-management practices with ejidos characterised by stronger organisational structures showing better compliance with irrigation rules. The size of the farmer group within an ejido influences water management performance with smaller groups exhibiting better compliance with irrigation rules than larger, less organised groups. Biophysical attributes such as location within the irrigation system, irrigation technique used, and access to groundwater also impact water-management practices and perceptions of water scarcity. Farmers' perceptions of fairness in water distribution influence their satisfaction with Water User Association (WUA) services and their compliance with irrigation rules. Biophysical and social factors influence farmers' perceptions of water scarcity, including water distribution practices and organisational structures within their ejidos.
Danso et al. (2021)	[72]	Canada	Farmers' adoption of efficient irrigation technologies in light of water trading	Farmers are more likely to adopt efficient irrigation technologies when the net gain from water trading is higher than the cost of adopting the technology, indicating a rational adoption approach. The provision of subsidies can encourage farmers to adopt improved irrigation technologies, especially when the expected net returns under the subsidy approach exceed those from continuing with existing practices. The study also found that high crop price regimes can encourage farmers to adopt improved irrigation technologies to produce profitable crops. Water trading and improved irrigation technologies allow farmers to grow high-value crops and increase profits. Farmers are more likely to make decisions that optimise limited water resources during droughts or reduced water entitlements.
Gao et al. (2024)	[93]	Australia	Farmers' seasonal irrigation water usage	Seasonal rainfall moderately influences irrigation water usage on cotton farms with higher rainfall leading to reduced irrigation water requirements. Soil properties such as clay content and bulk density were significant predictors for corn/maize, while the percentage of sand content was important for cotton. For rice, the soil's total mass of nitrogen (NTO) was a key driver of seasonal irrigation water usage. Irrigation practices, such as duration, frequency, and intensity, significantly impacted seasonal irrigation water usage for crops like corn/maize, cotton, and rice. Different crops favoured different subsets of irrigation and soil predictors. For example, while the number of irrigation days was important for all crops, other predictors, such as the bulk density of soil and self-mulching clay, were important for specific crops. Seasonal rainfall moderately influences irrigation water usage on cotton farms, with higher rainfall leading to reduced irrigation water requirements.
Ricart and Rico-Amorós (2021)	[88]	Spain	Farmers' adoption of treated wastewater and willingness to invest in water technologies like constructed wetlands (CWs)	About half of the surveyed farmers used treated wastewater for irrigation, but only one third considered the water quality standards good. The main factors influencing treated wastewater use were crop selection and water quality standards. Most farmers were aware that climate change is occurring and poses risks to agriculture. However, awareness varied based on age, education, and farming experience. The top climate change impacts perceived by farmers were increased droughts, warmer temperatures, and water scarcity. Farmers with higher levels of education, such as those with professional studies, may have a deeper understanding of environmental issues and water management techniques and might be more inclined to adopt water-saving technologies and practices compared to those with lower levels of education. While most farmers agreed on the need for adaptation, treated wastewater use was considered the preferred measure. CWs were seen as a way to improve both water supply and pollution. Farm size, irrigation methods, and water consumption influenced farmers' willingness to invest in water technologies like CWs.

Table A2. *Cont.*

	Reference Number	Country of Study	The Type of Water-Use Behaviour Investigated	Key Findings (Factors Influencing Water-Use Behaviour)
Aldaya et al. (2023)	[91]	Spain	The effect of water pricing on farmers' choice between irrigated and rainfed crops as well as their overall water use per hectare	The northern and middle regions of the canal tend to abandon irrigation and substitute irrigated crops with rainfed crops when water prices increase due to abundant rainfall and lack of suitable crops. Different regions respond diversely to water price changes based on geographical location, climate, and soil characteristics. The southern areas, which are warmer and drier, depend more on irrigation and are more sensitive to water price increases. They introduce fruit trees and vegetables, showing higher water use, gross margins, and labour values. It was observed that water demand decreased with rising water prices, indicating a trend towards water conservation. This decrease in water demand initially exhibited an elastic phase, which was followed by an inelastic stretch where further increases in water price had diminishing effects on water use reduction. Economic factors such as gross margins and labour values also impact water-use decisions. Southern regions, known for their high productivity, exhibit larger gross margins and labour values, making them more responsive to changes in water prices. Water pricing is found to be an effective policy instrument to encourage water-saving behaviours as water use decreases with an increase in water price above 0 EUR/m^3.
Ren and Yang (2023)	[89]	China	Farmers' adoption of various water-saving strategies in response to water scarcity and increasing water prices	The study finds that social–ecological system factors like resource system size, productivity, predictability, resource unit mobility, number of users, norms, leadership, governance system, and monitoring processes affect farmers' choice of water-saving strategies. The size and predictability of land resources facilitate the adoption of water-saving strategies, while water resource factors inhibit them. The productivity of the resource system promotes negative strategies but hinders positive ones. Land-related factors positively impacted water-saving strategies, while water-related factors had the opposite effects, highlighting the importance of resource gap awareness. At low levels of water price increases, a higher number of users (households or farmers) generally hinders the adoption of both positive and negative water-saving strategies due to increased transaction costs and complexities in coordination. However, as policy shock intensifies with higher water price increases, this adverse effect diminishes, and more users start to facilitate the adoption of negative water-saving strategies. This shift suggests that larger groups can better mobilise resources and support under more substantial external pressures, mitigating the negative impacts of policy shocks. The mobility of land resources, facilitated by property rights and land transfer, significantly influences farmers' adoption of positive water-saving strategies during intense policy shocks, offering them greater flexibility and risk mitigation than water resources.
Cui et al. (2022)	[73]	China	Farmers' adoption of climate-adaptive technology	The findings show that the child-rearing burden significantly negatively impacts farmers' adoption of climate-adaptive technology. The burden reduces farmers' risk appetite for economic capital and increases non-agricultural employment, hindering technology adoption. Higher levels of education among farmers are positively associated with adopting climate-adaptive technology. Education broadens farmers' understanding and ability to implement these technologies. Improved health among farmers positively influences the adoption of climate-adaptive technology. Better health enables farmers to engage more effectively in learning and implementing these technologies. Larger cultivated land scales in farming families positively correlate with adopting climate-adaptive technology. Higher potential agricultural production income motivates farmers to adopt these technologies. Farmers with higher disaster awareness are more likely to embrace climate-adaptive technology. The precise recognition of agricultural production losses due to disasters promotes the adoption of resilient technologies.

Note: Source: Authors' compilation.

Table A3. Key topics explored in U.S. and Chinese studies on water-use behaviour.

Author(s)/Year	Reference Number	Country	Key Topics Covered
Cui et al. (2022)	[73]	China	• Government policies and social security • Insurance and risk preferences • Environmental impact assessments • Role of the surrounding environment in technology adoption • Psychological factors in farmers' decision making
Ren and Yang (2023)	[89]	China	• Planting structure • Water pricing policies • Social–ecological system dynamics • Strategy transformation processes
Yuan et al. (2021)	[25]	China	• Farmers' behavioural characteristics and decision making • Agent-Based Modelling (ABM) in agricultural water management • Impact of water management policies on farmers' responses • Crop choice and water use at various geographical scales
Xiuling et al. (2023)	[65]	China	• Impact of risk aversion on water-saving irrigation technology adoption • Role of technical training in the adoption of water-saving irrigation technology • Integration of risk aversion and technical training • Implications of interaction items on adoption behaviour • Current adoption rate and enthusiasm for water-saving irrigation technology
Mi et al. (2021)	[63]	China	• Water management strategies and agricultural productivity • Role of social networks and economic Incentives • Tailored water management solutions
Wang et al. (2023)	[41]	China	• Water-Saving Agriculture (WSA) adoption intention • Theoretical model development • Psychological factors in farmers' decision making • Awareness of environmental consequences • Intention–behaviour gap
Wang et al. (2021)	[62]	China	• Adoption and sustained adoption of water-saving technologies • Impact of water scarcity • Role of cooperative organisations and education
Berthold et al. (2021)	[64]	The U.S.	• Respondents' basic characteristics • Familiarity with and use of irrigation-scheduling methods • Barriers to the adoption of SIS methods • Factors influencing the adoption of SIS methods • Regression analysis of factors affecting knowledge and adoption of SIS
Fan and McCann (2020)	[66]	The U.S.	• Irrigation practices and scheduling • Adoption of water conservation practices • Multilevel modelling of water-use behaviour • Rebound effects of irrigation efficiency • The policy implications of water conservation practices and their economic impacts
Bailey et al. (2021)	[67]	The U.S.	• Influence of peer networks on irrigation technology adoption • Irrigation practices and technologies • Socioeconomic characteristics and education • Regional variations and conservation programs • Policy implications and extension services
Irmak et al. (2022)	[81]	The U.S.	• Automated irrigation analytics and monitoring • Irrigation water management technologies • Irrigation water withdrawal and use characteristics • Regional water footprint and irrigator behaviour • Real-time monitoring of farm-level irrigation dynamics
Roberts et al. (2022)	[69]	The U.S.	• Perception of water-saving practices over time • Water measurement and metering • Irrigation technology and automation • Crop-specific irrigation practices
Reints et al. (2020)	[71]	The U.S.	• Adoption of water-efficient technologies and management practices • Socioeconomic and farm characteristics • Informational factors and extension services • Regional climate and water conditions • Adaptation to climate change
Davenport et al. (2022)	[59]	The U.S.	• Drought risk perception and irrigation behaviour • Social and psychological dimensions of risk • Technocratic understanding vs. experiential framing • Influence of farm characteristics on adaptation • Climate change and water scarcity scenarios

Table A3. *Cont.*

Author(s)/Year	Reference Number	Country	Key Topics Covered
Fischer and Sanderson (2022)	[86]	The U.S.	• Physical water context and water conservation norms • Worldviews and climate change beliefs • Awareness of consequences and ascription of responsibility • Values and water conservation norms • Irrigators vs. dryland farmers

Note: Source: Authors' compilation.

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