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Defining sustainability in agricultural water management using a Delphi survey technique

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ABSTRACT

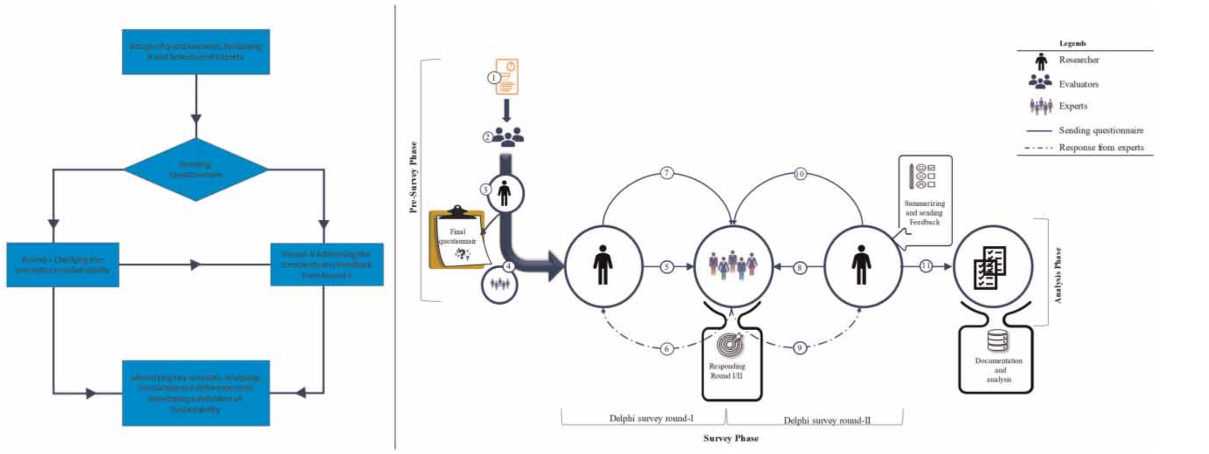
Sustainable water management measures are being developed to address the challenges posed by agriculture runoff and leaching on water resources. These measures are based on experts' opinions from various sectors and disciplines, ensuring that all stakeholders' perspectives are considered. For this, establishing a common understanding of 'sustainability' is essential to avoid misunderstandings, conflicts, and operational challenges. In this research, the Delphi survey technique was utilized to develop a definition of 'sustainability' in agricultural water management (SAWM) by considering the interdisciplinary group of experts from different parts of the world and those involved in a Horizon 2020 Research and Innovation Action. Twenty-six experts' perspectives on environmental, economic, and social dimensions of sustainability were assessed, and identified key concepts included climate change, water quality, water availability, stakeholder participation, capacity building, subsidies, and incentives. These concepts were used to define sustainability for multi/interdisciplinary project settings. The definition was validated with consortium members of the project in the regular consortium-wide meetings and used in the respective deliverables dealing with sustainability. The results serve as a foundation for communication between the involved actors and the project's definition of 'sustainability.' One recommendation from this work for broader policy formulation for SAWM in Europe is to prioritize farmer needs and focus on environmental sustainability.

Key words: Agriculture, Climate change, Expert knowledge, Multidisciplinary, Stakeholder, Water policy, Water quality

HIGHLIGHTS

- The research in agricultural water sustainability is essential to find pathways that optimize food production, limit water resource pollution, and promote sustainability of water management practices.
- The absence of a common definition of sustainability can lead to miscommunication among partners due to varying interpretations resulting in ineffective collaboration, confusion, and a lack of coordination.
- The Delphi survey technique is a powerful tool to capture diverse opinions from various experts in a complex discipline like "Sustainability".
- Climate change, the environmental pillar of sustainability, and farmers as major stakeholders should be taken into prime focus when dealing with sustainable water management in agriculture.

GRAPHICAL ABSTRACT



1. INTRODUCTION

In Europe and elsewhere, it has been hard to find sustainable solutions for agriculture which allow for the production of food while maintaining the positive status of water resources. This is a multi-faceted problem which is grounded in (a) a common understanding of sustainability and (b) the translation of scientific evidence of sustainable solutions into policy recommendations. In addition, sustainability may mean one thing in an 'agricultural context' and another in a 'water context'. Bringing these multiple visions together is challenging both in a project setting as well as in the wider science-policy realm. Having a common definition of sustainability in agriculture is difficult due to its complex and adaptable nature (Velten *et al.*, 2015). The absence of a common definition can lead to the miscommunication among partners due to varying interpretations. This can result in ineffective collaboration, confusion, and a lack of coordination, which is often referred to as a 'dialogue of the deaf' (Sauvé *et al.*, 2016).

Sustainability, as a concept, is vague and oxymoronic, which can lead to operational difficulties upon implementation (White, 2013). In the past, sustainability has been defined in slightly different ways, reflecting institutional values. The Brundtland Commission first defined sustainable development in 1987 as '*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*' (Brundtland, 1987). This definition laid the foundation for sustainability's three-dimensional concept: social, environmental, and economical. Different institutions developed the contextual definition of sustainability based on the purpose and scope of the work to address the complexity of operationalization. The United Nations Food and Agricultural Organization (FAO) defines sustainability in agricultural water use as '*sustainable water use balances the social, human, economic and environmental demands for good quality freshwater (and the benefits) with the long-term availability of utilizable and replenishable surface and groundwater resources. It seeks to do this at minimum economic, social and environmental cost*' (FAO Regional Conference Session, 2022). The World Bank (2019) defines sustainability as '*improved water stewardship*' that '*pays high economic, environmental and social dividends*.' Besides this, numerous contextual definitions of sustainability have been proposed by different researchers. The International Commission on Irrigation and Drainage (ICID) defines sustainability as '*the management of a watershed system with sustainable technological options, which may ensure the sustainability of the land, agriculture, and forestry or its combinations to conserve natural resources, with adequate institutional and economical options*' (Vishnudas *et al.*, 2005). This diversity in definitions reflects the multidisciplinary nature of sustainability in agricultural water management (SAWM) and the different priorities and perspectives of institutions involved in its discourse.

However, without a shared understanding of sustainability, policymakers face difficulties in translating scientific research and expert advice into effective policies that integrate environmental, social, and economic dimensions of sustainability in agricultural water management (Quevauviller *et al.*, 2005; López-Rodríguez *et al.*, 2015). Defining sustainable options is challenging due to different expert opinions and stakeholder priorities (Gatto, 1995). This is also partly due to complex underlying natural conditions affecting pollution and water resource vulnerability. Finding sustainable solutions requires the involvement of actors from diverse backgrounds, as well as inter/multidisciplinary research (Lang *et al.*, 2012). Among expert and stakeholder viewpoints, SAWM can be understood differently, leading to communication difficulties and hindering the development of coherent and effective sustainability policies (Gremmen & Jacobs, 1997; Dogmus & Nielsen, 2021). The lack of clarity also undermines engagement and collaboration, hindering the inclusion of diverse perspectives and limiting the potential for innovative and effective policy solutions (Ratiu & Anderson, 2015; Moore *et al.*, 2017; Ben-Eli, 2018).

As such, SAWM is directly linked with multiple different goals of the United Nations' Agenda for its 2030 Sustainable Development Goals (SDG), in particular, SDG 6: Clean Water and Sanitation, SDG 2: Zero Hunger, and SDG 13: Climate Action (Tsani *et al.*, 2020). SAWM comes in many forms in SDG 6, such as in Target 6.3 (maintaining water quality), Target 6.4 (sustainable withdrawal), Target 6.5 (implementation of Integrated Water Resources Management (IWRM)), and Target 6.6 (restoring the ecosystem). At the European level, the European Union (EU) Water Framework Directive (WFD) protects water resources (EU Directive, 2019), whereas the Common Agricultural Policy (CAP) focuses on agricultural production which also includes actions to limit water pollution such as the limitation of fertilizer use and the implementation of protective riparian buffer strips (Grizzetti *et al.*, 2021). However, the limits for fertilizer use may not always be in line with the water quality needs of the adjacent river basin. A better understanding of sustainability may help streamline agricultural and environmental policies to avoid poor practice and compliance. The absence of a clear definition creates challenges in identifying appropriate goals, targets, and indicators. This hinders the ability to assess progress, monitor impacts, make informed decisions, and formulate policies. A common notion could thus (a) ease communication among partners by reflecting individual priorities and operational criteria, which are subjective and case specific (Gatto, 1995). Arriving at a shared definition of sustainability may (b) support effectively translating scientific knowledge into policy making.

While having a clear definition for sustainability in general is crucial especially for policy making, understanding more specifically SAWM in the context of technical project-level activities is equally relevant. By leveraging the expertise and knowledge of various disciplines and stakeholders, this research focuses on the latter and aims to (1) identify 'key concepts' for SAWM, (2) analyse similarities and differences in the perceptions of experts on SAWM, and (3) arrive at an agreed definition of SAWM in an EU project context. A questionnaire was sent to experts from academia, research institutes, and small and medium-scale enterprises working on water retention and nutrient recycling solutions in agriculture. The study included nine countries across Europe's boreal, continental, and Pannonian climate regions, as well as experts outside Europe.

This article will follow the following structure: Section 2 will cover the methodology, Section 3 will present the results, Section 4 will include a discussion, and finally, Section 5 will contain the conclusion.

2. MATERIALS AND METHODS

2.1. Delphi survey as a theoretical background

This research was focused on defining sustainability in the context of SAWM in a multidisciplinary project setting. To define sustainability in such a setting, a systematic literature review is often used. However, Yuan &

Hunt (2009) argue that they are more technical, guided by fixed criteria, and create a challenge when being incorporated into the practical field. Since sustainability science has shifted from a 'technical approach' to a 'social learning approach' (Pahl-Wostl *et al.*, 2008), this type of study demands engaging stakeholders or experts to produce a consensus or technical inputs. Focus group discussions, stakeholder workshops, (key informant) interviews, consensus-based surveys, etc., are all commonly used stakeholder engagement methods in multidisciplinary projects (O'Haire *et al.*, 2011). The former two methods were not usable when conducting this survey due to pandemic restrictions and fund limitations. (Key informant) interviews were discarded considering that the definition of sustainability requires broader agreement upon terminologies. So, to collect viewpoints from a broader audience, the consensus-based method was chosen over other methodologies in this research. There are three types of consensus-based approaches: the Delphi approach, the Consensus Development Conference (CDC), and the Nominal Group Technique (NGT) (James & Warren-Forward, 2015). The cited authors state that CDC and NGT are more suitable for face-to-face interaction and are time limited; Delphi, however, has no such boundaries. Thus, the Delphi survey method was considered appropriate for this survey.

The Delphi survey tool (named after the famous oracle at Delphi from ancient Greece) was initially developed by the Rand Corporation for technological forecasting by US armed forces (Hasson *et al.*, 2000; Habibi *et al.*, 2014). It is a technique for collecting opinions from a group of experts to get a collective response (Brown, 1968). In addition, it is a method for organizing group communication so that a group of people may solve a complex problem (Hugé *et al.*, 2010; Allen *et al.*, 2019). The Delphi survey tool is highly esteemed for its aptitude in gathering qualitative information from a diverse pool of experts, irrespective of their geographical location or academic proficiency (Sekayi & Kennedy, 2017). It can be used in a variety of decision-making contexts because they provide a structured, systematic, and cost-effective approach to gather and analyse the opinion (Needham & de Loë, 1990). Brown (1968) mentioned the initial use of the Delphi survey on defence projects for creating army strategies and suggested the potential applications for medical diagnostics, business forecasting, expert investment counselling, financial planning, and policy models. Delphi surveys have been successfully utilized in econometric models for the environmental impact assessment (Solomon, 1985), for understanding social science in the ecosystem management (Endter-Wada *et al.*, 1998), in policy discussions (Critcher & Gladstone, 1998) and participative policy making (Hilbert *et al.*, 2009), in identifying sustainability factors (Roy *et al.*, 2014) or criteria for environment assessment (Hanna & Noble, 2015) and impact assessment (Carvalho *et al.*, 2017), in developing indicators for the sustainable food system (Allen *et al.*, 2019), in ecology and biological conservation (Mukherjee *et al.*, 2015; Musa *et al.*, 2015), challenges to sustainable drinking water services (Nelson-Nuñez *et al.*, 2019), just to name a few. The Delphi survey employs a systematic and interactive method of approaching experts in a specific field in order to generate opinions to help reach decisions (Hanna & Noble, 2015). The fundamental difference between ordinary surveys and the Delphi survey method is that it is structured, has iterations, and contains a feedback phase (Lilja *et al.*, 2011). Though the Delphi survey has been repeatedly used in diverse research domains, an extensive literature review shows no universal guidelines to date (Hasson *et al.*, 2000; Spranger *et al.*, 2022).

2.2. Application of Delphi survey for defining SAWM

Defining sustainability is contextual and case specific, so we considered a multidisciplinary project called WATERAGRI to define this concept in the context of the agricultural water management in agriculture. This is a European-funded H2020 project on sustainable water management, which unites 23 consortium members throughout Europe and from various disciplinary backgrounds with a strong focus on water and environmental research. WATERAGRI explores the sustainability of water retention and nutrient recycling solutions in agriculture through 10 case studies in 9 European countries across 3 climatic zones (WATERAGRI Project – report, 2020). Consortium members come from academia, research institutes, and small- and medium-scale enterprises. Jargon, understanding, and concepts around sustainability differ amongst consortium partners, which is an issue specifically for those conducting sustainability assessments of water retention and nutrient recycling solutions. Finding a common language is therefore considered crucial for coherent results and the creation of cohesive recommendations for stakeholders. When it comes to ecology and conservation, the Delphi survey technique has been classified into four categories by Hasson & Keeney (2011) as cited by Mukherjee *et al*. (2015): as decision, scenario, policy, and argument. The cited author further mentions that selecting a particular category is contingent upon the context and specific questions that must be addressed. It is possible to combine these categories based on the specific issue at hand, as they are not mutually exclusive. Thus, this research utilized a mix of decision Delphi (to identify different issues and concepts) and Policy Delphi (to elicit divergent opinions) survey methods.

While there are no specific guidelines on carrying out a Delphi survey, the process is in general guided by an iterative process of multiple rounds. Often, it is limited by time. In this current case, a three-step process was chosen that included (1) a pre-survey, (2) a first round, and (3) a second round (Figure 1). The pre-survey phase was introduced to support the rather natural science-driven authors in adjusting and improving the survey design. (Social science) experts from the project (here called evaluators) were asked to provide structured comments to an initial survey (see Section 2.2.1 for more detail). The two survey rounds consisted of open and closed (ranking) questions with the aim of looking for consensus across the proposed concepts. Consensus was defined as more than 60% of the participants (here called experts) agreeing on the high (or low) rank of a concept. The second survey round served to address aspects that were raised by experts in the first round through the open questions and reassess concepts that yielded conflicting results in the first round. The subsequent sections explain the steps in more detail.

2.2.1. Pre-survey phase

The pre-survey phase (referring to Figure 1 with subsequent steps in [..] parenthesis) consisted of [1] drafting an initial questionnaire, [2,3] an evaluation of the quality and respective recommendations for improvements to the questionnaire by evaluators, and [4] identifying the experts that should partake in the full survey.

A non-systematic literature review was conducted to formulate the initial questionnaire [1] to find the appropriate content and method for designing the questionnaires. The content was searched for on Google Scholar and Scopus, focusing on different sustainability and sustainable water management articles in agriculture. The keywords used for the search were as follows: *Sustainability, Social sustainability, Economic sustainability, Environmental sustainability, Agriculture, Water management, Irrigation, and European agriculture system*, with (AND) and (OR) as logical operators. This resulted in a draft questionnaire using three kinds of questions and sections: (a) questions on a Likert scale, where experts evaluated their knowledge on sustainability and rated the importance of SAWM based on their perception. This helped the analysis of the level of knowledge of experts and the relevance of study; (b) ranking questions to rank the dimensions of sustainability, type of stakeholders, and different concerns on SAWM. This helped prioritize the pillar of sustainability, identify the major stakeholders, and distinguish between major/minor concerns in sustainable water management; (c) open-ended questions, where experts could define the three pillars of sustainability and key issues to be addressed based on their experiences. This helped identify the key concepts and concerns related with specific locations. Twenty-one questions (questionnaire in Annex A) were developed for different thematic profiles, as shown in Table 1

While expert evaluation of questionnaires [see Steps 2 and 3 of Figure 1] has not gained much factual attention, it is sometimes used in research for validation, adding value to questions and avoiding lower survey data quality (Olson, 2010). Incorporating interdisciplinary knowledge from various fields was essential in this survey,

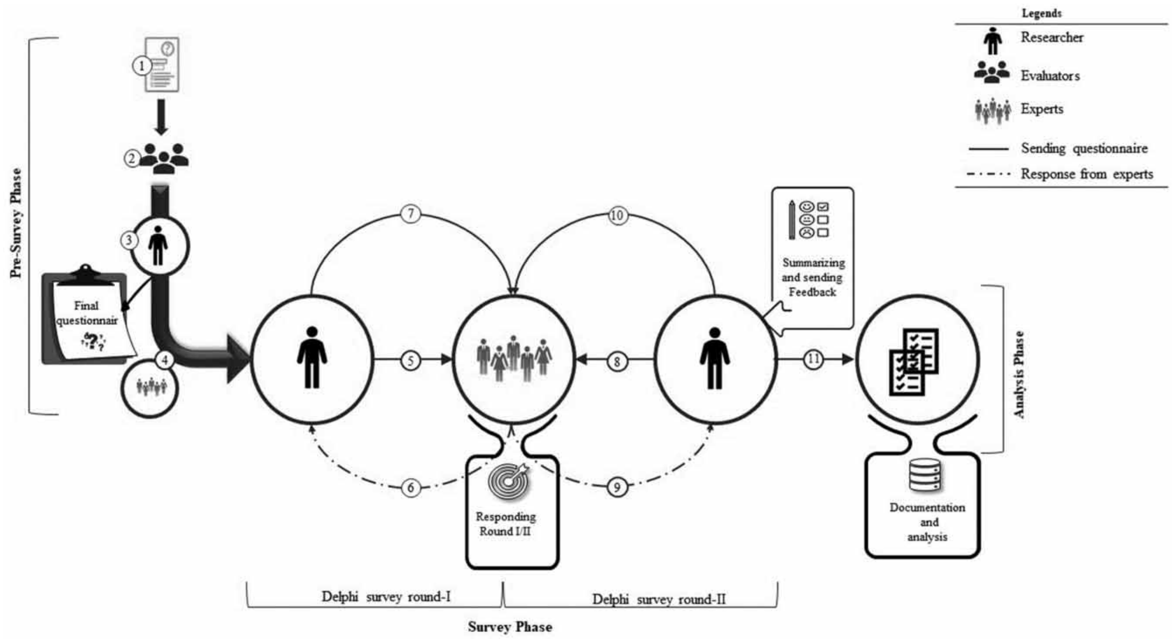


Fig. 1 | Graphical illustration of the overall methodology of the Delphi Survey at different phases: (a) pre-survey phase: 1, questionnaire design; 2, selection of evaluators; 3, revision/update of the questionnaire; 4, identification of experts; (b) survey phase: 5, sending questionnaires to experts; 6, returning the round-I responses from the experts; 7, sending summaries of round-I; 8, sending questionnaires for round-II; 9, returning the responses from Round-II; 10, sending feedback to the experts; (c) analysis phase: 11, documentation and analysis.

particularly due to the authors' technical background. The initial questionnaire was evaluated by three people (hereafter called evaluators) knowledgeable in sustainability assessments, mainly focusing on social, environmental, and economic dimensions. An interdisciplinary team of evaluators brings a range of perspectives and expertise to the table (Wagner *et al.*, 2011). They challenge assumptions, identify potential biases, and provide unique insights that might be missed by a single-discipline approach (Haythornthwaite, 2006; Ikart, 2019). Such diverse viewpoints enrich the questionnaire development process, improving its relevance, clarity, and sufficiency across different contexts.

Table 1 | Type of questions.

Thematic profile of questionnaire	Number of questions	Aim
General understanding of subject matter	5	To identify which pillar of sustainability is preferred by the experts, identify the key stakeholders in SAWM, and capture the expert's blueprint concept on SAWM.
Social sustainability	5	Capture the expert's in-depth knowledge of SAWM in each pillar of sustainability and identify the hotspots and major concerns, which helps formulate key concepts.
Environmental sustainability	5	
Economic sustainability	4	
Conclusion and feedback	2	To capture feedback on both the Delphi survey method and subject matter.

A two-step evaluation of the questionnaire was applied, where evaluators were first asked to review the content and then evaluate the questions based on their relevance, clarity, and sufficiency. The first step evaluated the content, wording, grammar, and flow of the questionnaire. Regarding the content, the evaluator mentioned the lack of basis for assessment in the questions, which can create a bias in response by overestimating or underestimating the knowledge they acquire. This was addressed by introducing 'based on your experience' in each question. In the ranking questions, evaluators suggested providing a 'multiple ranking option' and the section for feedback/remark with an 'additional if any' option. As part of the evaluation process, the evaluators recommended incorporating the concept of 'water stress' as it is often overlooked when addressing water management – a crucial topic that requires thorough comprehension. This term was well received by other experts who participated in the evaluation. Furthermore, experts recommended collecting sustainability assessment methods from the respondents, which was subsequently incorporated into the questionnaires. Furthermore, each question was quantitatively evaluated on a five-point Likert scale, for Relevance, Clarity, and Sufficiency (Result Annex C). No major changes were suggested here. The questionnaire evaluation served as the draft questionnaire's quality control point before general administration.

The selection of experts [4] in the Delphi survey is recognized as the major step, and there are different views regarding the best choice of experts (Belton *et al.*, 2019). While Belton *et al.* (2019) suggest that experts should have a 'closeness to the topic of interest,' Prietula & Simon (1989) define an expert as '*a person who has substantial knowledge of the field, can explore the boundaries of their area of expertise, and an informed layperson.*' There is no 'magical formula' or strict guidelines for selecting experts for the Delphi Survey (Devaney & Henchion, 2018). However, Belton *et al.* (2019) suggest that researchers use common sense to define meaningful criteria for selecting experts, based on the nature and purpose of the study. The selection of experts in this survey was thus made using the broader network recommended by evaluators, based on non-probabilistic and purposeful sampling techniques (Hasson *et al.*, 2000). In this sampling technique, the experts are selected based on the subjective judgement of the researcher, regardless of the number of participants in the survey. Experts from the selected case study project, WATERAGRI consortium members (9 WATERAGRI case study owners, 11 WATERAGRI solution providers), local WATERAGRI case study stakeholders (10), and people not related to the project in any way (9) were invited to participate in this survey.

2.2.2. Survey phase

A two-round survey [Steps 5–10 in Figure 1] was conducted between May 2021 and February 2022, with 21 questions in Round-I and 12 questions in Round-II. The former focused on clarifying concepts in the three dimensions of sustainability, whereas the latter was intended to clarify the remaining conflicts amongst the experts' responses. The survey was administered as an online survey due to the diversity of respondents from different locations, the COVID-19 pandemic situation, and travel expenses. The online survey tool *Webropol (*http://webropol.oulu.fi/) was selected due to the university's access to it. Since aesthetic appearance can significantly impact the amount and quality of data collected (Rathore, 2020), inbuilt features were used to make the survey aesthetically pleasing.

2.2.2.1. Inviting experts. Initial contact was made via official email, providing general information on the study, rules, and aims (Annex B). The case study owners of WATERAGRI were asked to recommend stakeholders related to the case study site in order to involve them in the study. The external experts were invited based on recommendations from senior researchers and colleagues. Participants were asked for consent to participate in the survey and were made aware of how the information provided was to be used. In general, this followed the principles of the European Union's General Data Protection Rules (GDPR) as well as the Privacy Policy of WATERAGRI. The questions were not compulsory on the understanding that 'no answer is also an answer' and due to a desire to provide flexibility for the respondents.

The survey was initiated by inviting 39 experts, of which 26 responded in Round-I and 25 responded in Round-II. The response rate differed across sections of questions in Round-I. The average number of respondents in the first section was 25, in social and environmental sustainability was 21, and in economic sustainability was 19. The number of respondents in the conclusion and feedback section was 19. This shows a gradual decrease in the number of respondents as the questions proceed, possibly due to exhaustion considering the numbers, required time, and complexity of the questionnaire. In Round-II, there was no significant variation in the number of respondents based on the type of question.

Two categories of experts were invited to participate in the survey, one representing Europe and the other from different parts of the world outside Europe. The European experts were divided based on three climatic zones: boreal, continental, and Pannonian. There was not equal representation from each climatic zone, and the number of respondents from continental zones was higher compared to others (Figure 2(a)). The respondents from the case study project consisted of three different types of experts, namely, case study owners, solution providers, and stakeholders. The respondents from the stakeholder group were comparatively low in number (Figure 2(b)). Regarding the gender distribution of participants, of 39 invited participants, 27 were males, and 12 were females. Though there were fewer female participants, their response rate was higher, 75% compared to 59% for male participants.

The working experience of experts in the water sector in terms of years showed that of 26 experts, 12 had experience of more than 10 years. Three experts had no related field experience, and two of them did not declare their experience (Figure 3(a)). The response regarding the profession of experts showed that 11 of 26 worked as researchers and six as professors/assistant professors. There were four engineers and five project managers (Figure 3(b)). This shows the diversity amongst experts regarding geographical coverage, work experience, and profession.

2.2.2.2. Delphi survey Round-I. The survey was initiated on 27 May 2021, with a timeframe of 2 weeks to respond. Some respondents requested clarifications and asked for an extension of response time, so flexibility

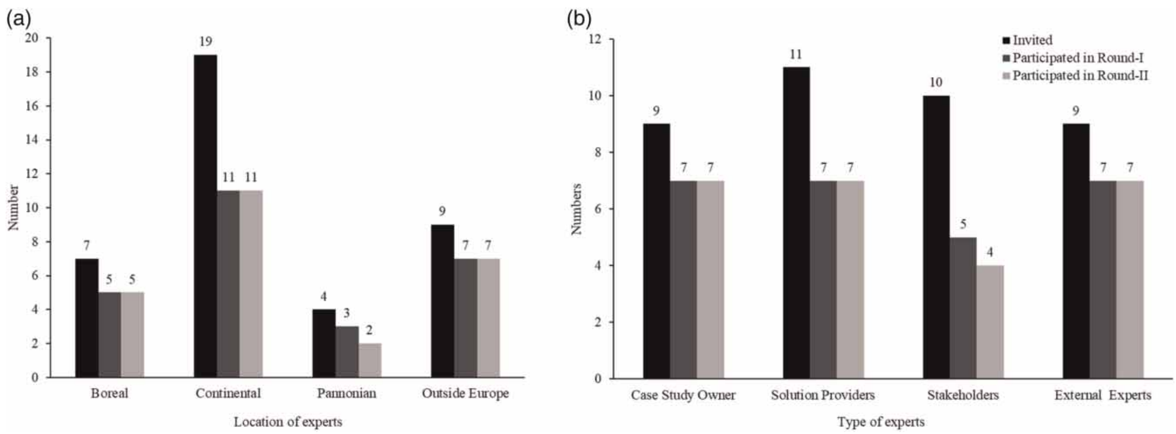


Fig. 2 | (a) Number of experts from different climatic regions within Europe and outside Europe and (b) type of experts from WATERAGRI project and external experts (outside Europe).

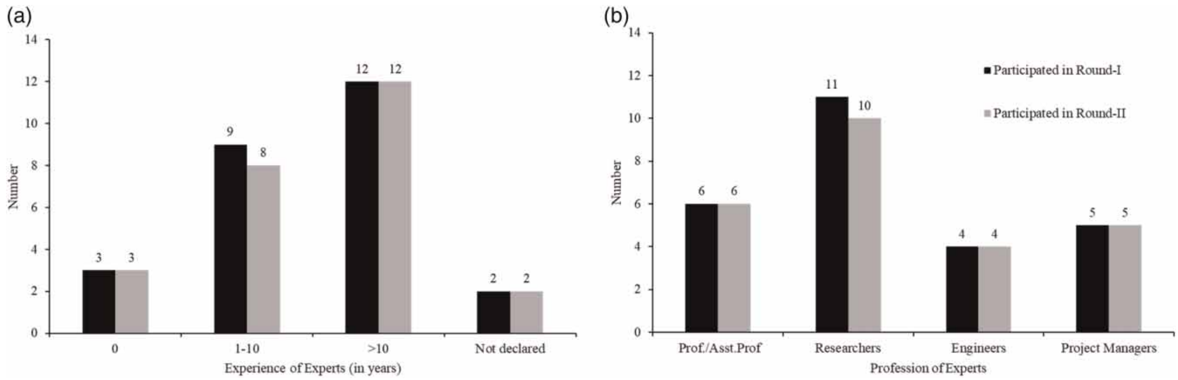


Fig. 3 | (a) Working years of experts in the field of water management and irrigation (or related to water and agriculture) and (b) diversity in the profession.

was provided to participants upon request. A reminder email was sent to individual participants during the process. The last reply was obtained on 4 September, and the survey was closed. The survey was responded to by more than two-thirds of the invitees.

Responses from Round-I were collected and analysed for similarities and differences to seek consensus across the responses. Defining the criteria for consensus in Delphi surveys is still a debatable topic, and no agreed position has been reached amongst researchers (Barrios *et al.*, 2021). Based on the various literature, a minimum of 51% of consensus is considered as acceptable for the Delphi survey (Loughlin & Moore, 1979; Hasson *et al.*, 2000). By considering this reference in this specific Delphi survey, a minimum of 60% consensus was used, as shown in Table 2.

2.2.2.3. Delphi survey Round-II. Round-II was conducted to (i) seek consensus on conflicting views from Round-I, (ii) seek feedback and, ideally, consensus on comments raised by experts in Round-I, (iii) list sustainability assessment methods that experts are familiar with, and (iv) seek feedback on the quality of the Delphi approach. Twelve questions were administered, among which 10 were on conflicts and comments, one focused on collecting information about methodologies for assessing sustainability, and one on overall feedback for the survey. All the questions in this survey were of the ranking type to ease the work of the experts. The ranks for each question were similar to the ranks from Round-I. In Round-II, a summary and

Table 2 | Criteria for measuring consensus.

Measure of consensus	Criteria
Consensus on open-ended questions	At least 60% of the participants provide consistent views on the key concepts in general and on each theme of sustainability.
Consensus on ranking and Likert scale questions	At least 60% agreement on each issue from the respondents is required.
Consensus on issues raised by other experts	Agreement/disagreement of at least 60% of the rest of the experts.

feedback from Round-I were provided to the respondents as this helped the overall effectiveness in gaining group consensus and stability of responses (Belton *et al.*, 2019).

The survey was administered on 17 November 2021, with a 2-week response period in the invitation letter (providing similar flexibility to Round-I). The last response was received on 7 February 2022 from 25 out of 26 experts, of which 15 were males and 9 were females.

Although the analysis phase [Step 11 in figure 1] is not widely recognized as a separate phase in many Delphi surveys, it involves managing data (quantitative and qualitative) and presenting the results (Day & Bobeva, 2005). For this survey, primary data management was carried out using the survey website webropolsurveys.com and converting the responses into an Excel format. The final analysis of the research work was done after obtaining the last result from Round-II. The Round-I survey was concerned with conceptualizing SAWM, and Round-II with addressing the comments and conflicts. Qualitative data obtained from open-ended questions were analysed using manual text mining and identifying frequently repeated keywords. The ranking questions in the survey had varied ranks with the flexibility to provide the same rank for different options, depending on the context. Regarding these types of questions, the responses were categorized into high, medium, and low ranks. The term 'high' denotes the concerns that were ranked within the first three (1–3) by most experts. Conversely, 'low' refers to the concerns ranked within the last three by most experts and 'medium' that falls in between and were considered as neutral views. When analysing the responses from the five-point Likert scale, a response 'high' corresponds to a score of 4–5, while a 'low' corresponds to a score of 1–2. Responses with a score of 3 were considered neutral.

3. RESULTS

The subsequent subsection shows the combined collective results from Round-I and Round-II.

3.1. Environment sustainability as a primary concern in agricultural water management

In Round-I, experts were asked to prioritize the three pillars of sustainability (Figure 4) by ranking these in order of importance, i.e., Rank 1, Rank 2, and Rank 3. In this, 85% of the experts ranked environmental sustainability as their top priority. In the same, rank (means Rank 1) economic sustainability was mentioned by 35% and social sustainability by 32%. Moreover, 4 and 12% of experts ranked this pillar in the second and third positions, respectively. In addition, there is a significant number of experts who prioritize environmental sustainability in the first rank, in comparison to the other sustainability pillars. This highlights environmental sustainability as the primary concern in SAWM for this group of actors. Considering the response of Rank 2, economic sustainability was placed in this rank by 54% of experts, and social sustainability was placed in the same rank by 40% of experts. The Rank 3 results indicate that 28 and 12% of respondents, respectively, ranked social sustainability and economic sustainability in this tier. Therefore, the overall outcome reveals that the highest priority in the agricultural water management is environmental sustainability, followed by economic sustainability and then social sustainability.

The Venn diagram (Figure 4) displays the overlap of Rank 1 of three pillars of sustainability. Among the respondents, 15% assigned Rank 1 to all three pillars of sustainability. The Venn diagram shows that there is an 8% overlap between environmental and social sustainability, and an 11% overlap between environmental and economic sustainability. Interestingly, there is no overlap between the social and economic pillars of sustainability. In addition, the diagram indicates that only 8% of experts focused solely on the social and economic pillars, while 50% prioritized environmental sustainability. As Round-I of the survey showed a consensus without any conflicts, it is evident that the environmental aspect of sustainability was given utmost importance by experts when addressing the issue of water management in agriculture.

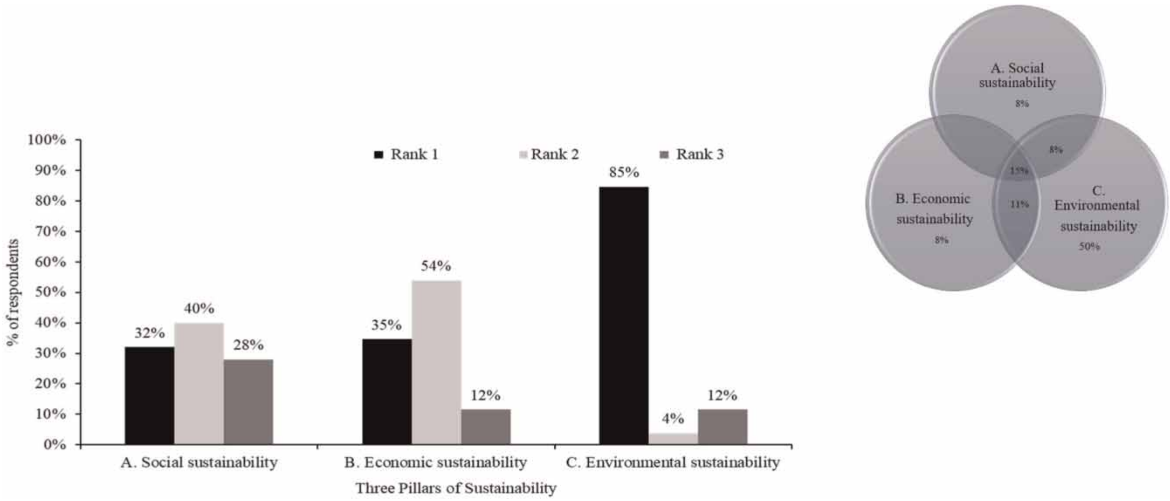


Fig. 4 | Ranking the three pillars of sustainability.

3.2. Major stakeholders in agriculture water management

A panel of experts was tasked with ranking the various stakeholders involved in the agricultural water management to identify the most significant ones. On ranking of eight different stakeholders, it was found that 92% of experts gave 'Farmers' a high rank, while only 4% gave them a low ranking (Figure 5(a)). The difference in responses between prioritizing farmers and other stakeholders was significant, emphasizing the consensus among experts that farmers are the primary stakeholders in SAWM. After 'Farmers', in terms of significance, 'Water user organizations', 'Agricultural cooperatives', 'Government authorities', and 'Institutional and regulatory actors' hold considerable importance.

The 'non-governmental organizations' were placed on the lower rank by 61% of experts and therefore considered as less important actors than other stakeholders in SAWM. In Round-I, experts gave conflicting opinions about whether 'supply chain actors' and 'private sector' should be ranked higher or lower. To resolve this, the issue was taken to Round-II for a consensus, which resulted in both stakeholder groups being placed in the higher rank (Figure 5(b)). Consequently, it can be deduced that the 'non-governmental organization' is the least prioritized stakeholder to be considered in SAWM.

3.3. 'Hotspots' within SAWM

To identify the hotspots within each pillar of sustainability, we collected the 'key concepts' mentioned in response to an open-ended question in the survey. We considered the top five words/phrases that met the consensus cutoff criteria and best describe the water management in agriculture, or have the closest meaning, as key concepts. These were collected manually by considering the frequency of repetition of key concepts in the response, examining each expert's response in each cluster of questionnaires.

Experts emphasized 'climate change', 'water quality', and 'water quantity' in response to the section on the general understanding of sustainability. Economic and social sustainability concepts such as 'economic cost' and 'stakeholder participation' were mentioned, but to a lesser extent than the previously mentioned concepts (Figure 6(a)). In terms of social sustainability, the concepts of 'stakeholder participation' and 'satisfaction and wellbeing' were the frequently acknowledge concepts. On the other hand, 'governance', 'equity', and 'capacity

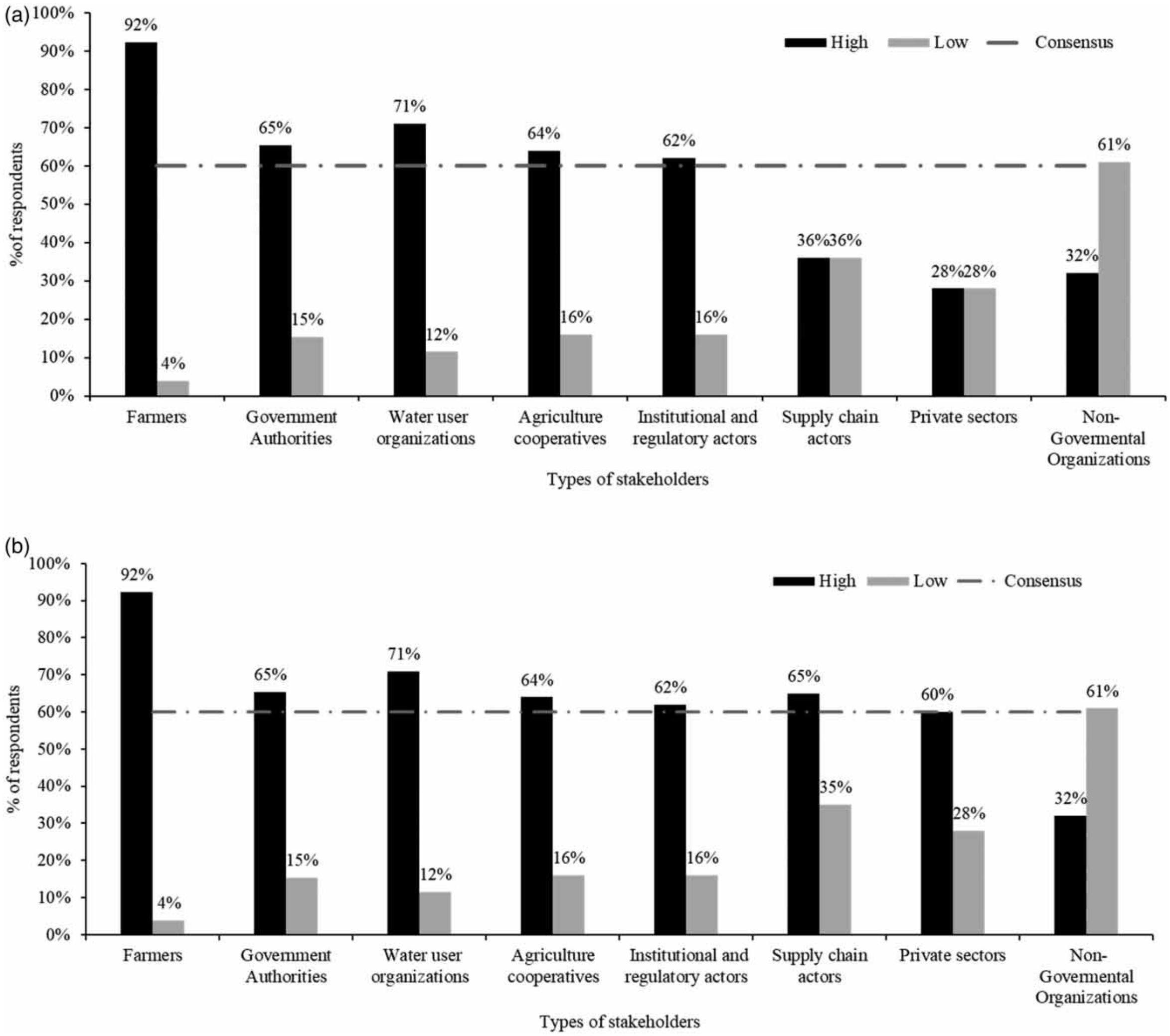


Fig. 5 | (a) Ranking of stakeholders in sustainable water management in agriculture in Round-I and (b) result of Round-II after gaining consensus in conflicting views.

building' were less frequently mentioned as important concepts in this section (Figure 6(b)). The results from the environmental sustainability section align with the results obtained in the general section, with 'water quality and 'water quantity' as the frequently highlighted terms. Furthermore, experts also showed concern about 'minimizing environmental degradation' and 'agriculture practices' (Figure 6(c)). In the section about economic sustainability, the terms 'affordable cost' and 'income and profit' were the most used. Conversely, 'meeting demands', 'subsidies', and 'incentives' were mentioned less frequently in the responses (Figure 6(d)).

Based on the overall results, it appears that the 'key concepts' outlined in the general section are predominantly focused on environmental sustainability. This is evident by the fact that most of the experts gave it a higher ranking. The primary area of focus within environmental sustainability is maintaining 'water quality'. This illustrates the issue of degrading water quality and the contribution of agriculture as the major sources of pollution. Economic sustainability concerns revolve around the 'affordability' of input and output costs in managing water

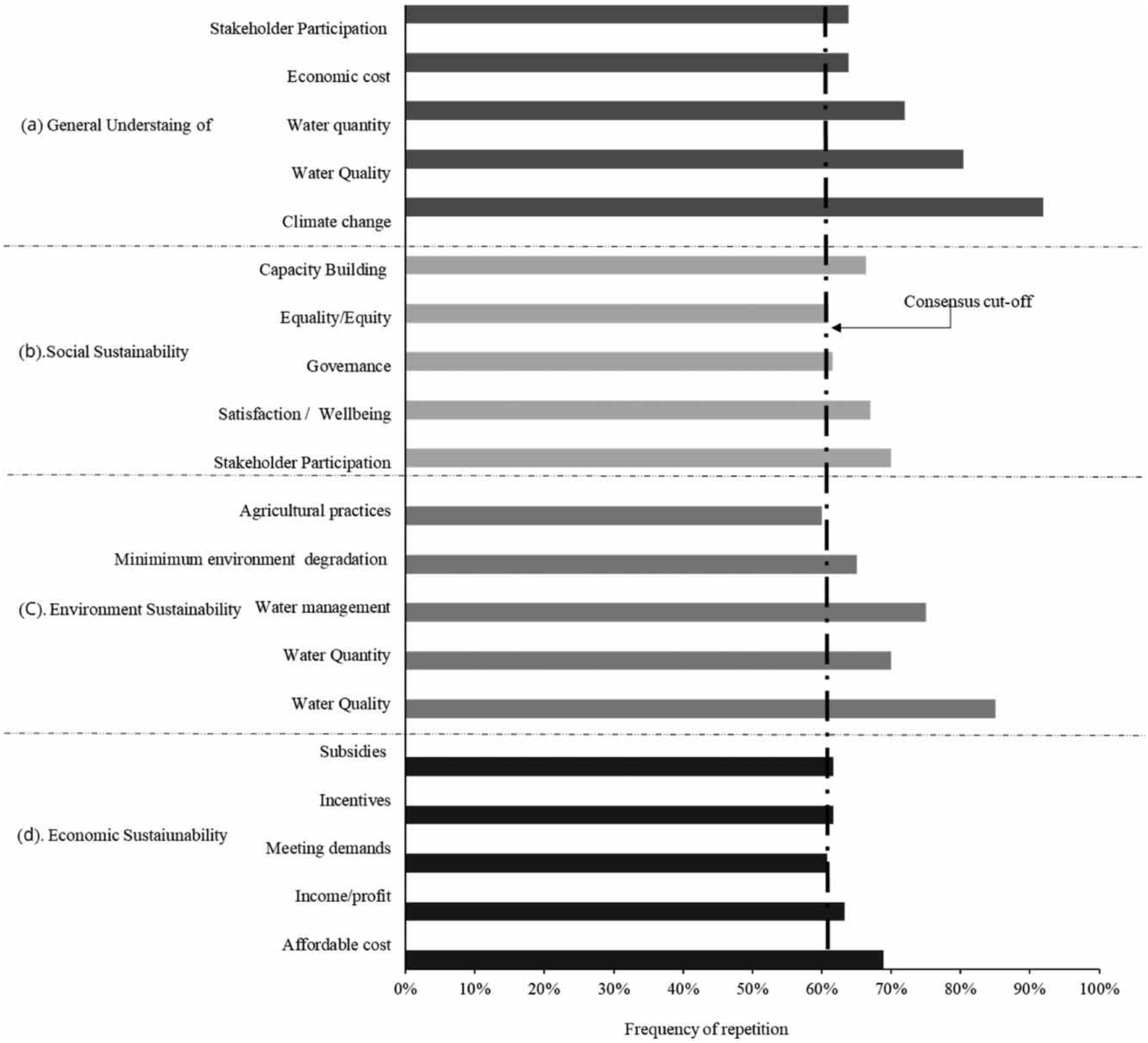


Fig. 6 | Major key concepts: (a) general understanding of sustainability, (b) social sustainability, (c) environmental sustainability, and (d) economic sustainability, where % is the frequency of repetition of keywords by experts.

resources for agriculture. Social sustainability emphasizes the importance of 'stakeholder participation' in agricultural water management to achieve sustainable outcomes. Since the frequently used key concepts were selected, no conflicts were observed upon analysing these responses. The highlighted key concepts serve as 'hotspot' areas that require attention by scientific communities dedicated to sustainable water management in agriculture. In addition, these key concepts serve as the cornerstone for developing the definition of sustainability.

3.4. Identified concerns in SAWM

Sustainable water management in agriculture is incredibly complex as it considers different concerns related to three dimensions of sustainability. It is therefore necessary to identify the major and minor concerns when prioritizing strategies for sustainable water management. Two approaches were used in Round-I to elicit concerns about SAWM. First, respondents were given a list of concerns and asked to prioritize them based on their experiences. Then, they were asked to discuss the major concerns in their locality. The result from the predetermined list is presented in a radar graph (Figure 7). The graph is made up of four sections, where 'high' refers to the concerns placed in the top three ranking by the maximum number of experts and 'low' refers to the concerns placed in the bottom three ranking by the maximum number of experts.

In response to the section on the general understanding of sustainability, the concerns around 'climate change', 'water availability', and 'on-farm water management activities' were ranked high by the maximum number of experts. Alongside this, 'irrigation technology', 'pollution and contamination of water bodies', 'farmers' economic status', and 'drainage system' were also ranked as high priority by most experts. The lower ranked concerns were 'social status of farmers', 'user participation', and 'law and legislation' by the maximum number of experts (Figure 7(a)). The issues in the higher ranks were related to environmental sustainability, and those in the lower rank were related to social sustainability, which aligned with the prioritization of sustainability (Figure 4).

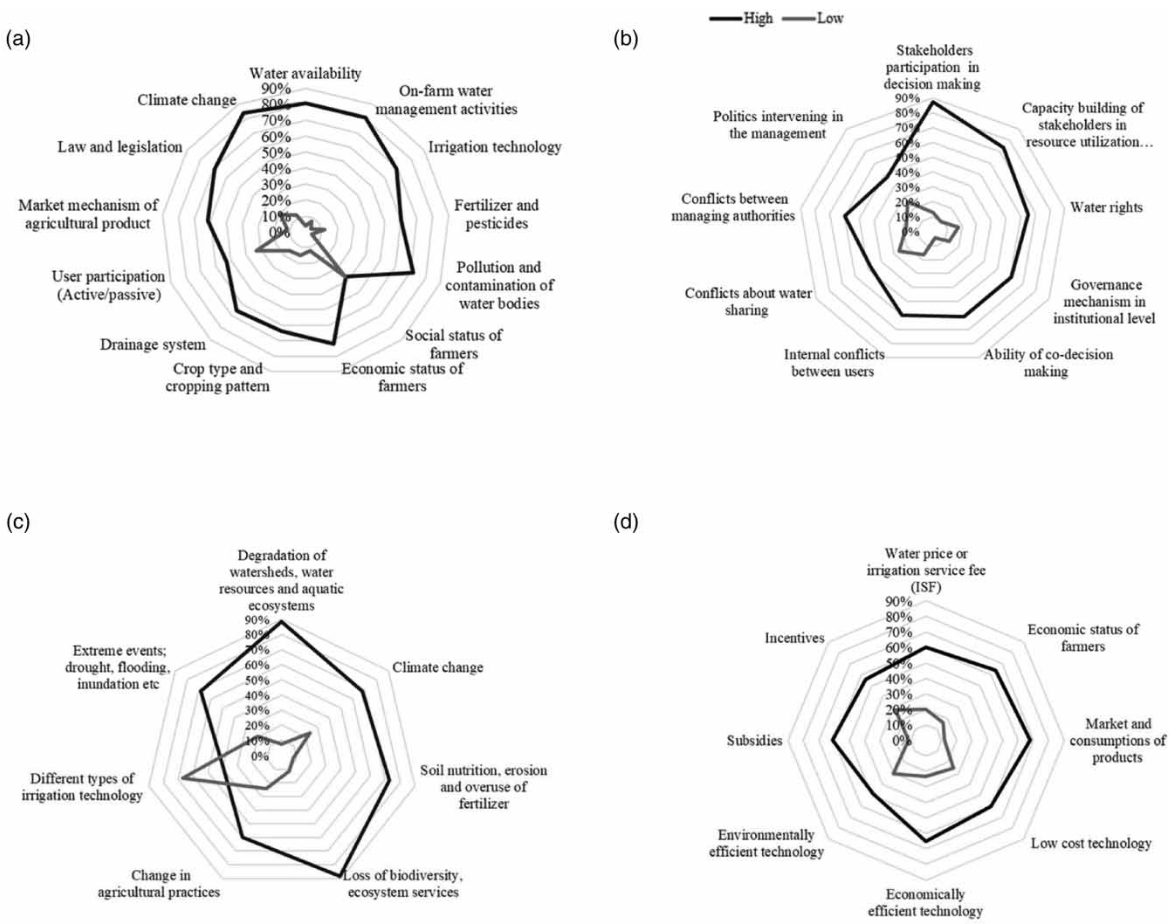


Fig. 7 | Major concerns in SAWM when considering (a) general understanding of sustainability, (b) social sustainability, (c) environmental sustainability, and (d) economic sustainability.

Given that the responses regarding the 'social status of farmers' and 'user participation' failed to meet the consensus cutoffs, both issues were considered contested and were carried over to Round-II to resolve the conflict.

From the section on social sustainability, most experts placed 'stakeholder's participation in decision making' in the high rank, considering it to be the major concern. 'Capacity building of stakeholders in resource utilization and management' was placed next to the aforementioned concern by experts. Alongside this, the other concerns ranked high were 'water rights' and 'governance mechanisms at the institutional level'. For this section, an equal number of participants ranked 'conflicts about water sharing' and 'politics intervening in management' in both higher and lower positions (Figure 7(b)). As a result, these issues were deemed conflicting and moved to Round-II for consensus. In response to discussing major concerns in their respective locality, most participants focused on the concerns related to 'capacity building' and 'governance mechanisms'. Concerns about 'degradation of watersheds', 'water resources', 'aquatic ecosystems', and the 'loss of biodiversity and ecosystem services' were ranked high by most experts in the section on environmental sustainability. The other issues in the high rank were 'soil nutrition, erosion, and overuse of fertilizer' and 'extreme events, drought, flood, inundation'. Most of the experts placed concerns around 'different types of irrigation technology' in the low rank (Figure 7(c)), making it the lowest prioritized concern in SAWM. In response to the major concerns in their respective geographical locations, experts mentioned 'maintaining water quality', 'weather extremes like drought and floodings', and 'climate change'. No conflicts were observed in the domain of environmental sustainability in Round-I. However, a participant brought up the issue of 'groundwater depletion', while the others stated that 'environmental sustainability is insignificant in agriculture as increasing production is the primary concern'. Both of these inputs were taken to Round-II for finding consensus. In the section covering economic sustainability, the experts placed great importance on 'economically efficient technology', 'market mechanisms', and 'consumption of products'. These were identified as major areas of concern. In addition, the economic status of farmers was also highly ranked by a significant number of experts (Figure 7(d)). In this section, 'environmentally efficient technology' and 'incentives' were considered to be in conflict, as both of these issues failed to meet the consensus criteria and were taken to Round-II for further consideration. In response to the concerns based on geographical location, experts mentioned 'cost and affordability' and 'subsidies'.

Based on the results, the concerns outlined in the ranking questionnaire align with those expressed by experts in their respective geographical locations. Furthermore, these concerns are consistent with the 'key concepts' identified in the previous section. This provides additional clarity on how consistently experts respond with consistent views.

The conflicts and comments observed in Round-I (presented in Section 3.4) were taken to Round-II for consensus. In this round, all the conflicting issues met the cutoff criteria for consensus and were therefore resolved (Figure 8). The concern on 'Conflicts about water sharing' from social sustainability was put on the lower rank by most of the experts by making it as the least concerned issue in SAWM. However, the concern on 'politics intervening in the management' was put in the higher rank in this round. The contested concern 'incentives' from economic sustainability was highly acknowledged and was put in the higher rank in this round. From the comment obtained from the experts the issue of 'groundwater depletion' was deemed a high priority and achieved consensus. In addition, most experts discarded a controversial statement on environmental sustainability mentioned by one of the experts.

Thus, the overall result showed that the selected group of experts focused on the environmental pillar of sustainability, with the farmer as the main stakeholder in the general consideration of SAWM. However, through an in-depth inquiry by considering all three pillars of sustainability, the same group of experts was able to identify the hotspots and major concerns of SAWM. This helped identify the key concept needed to formulate the definition

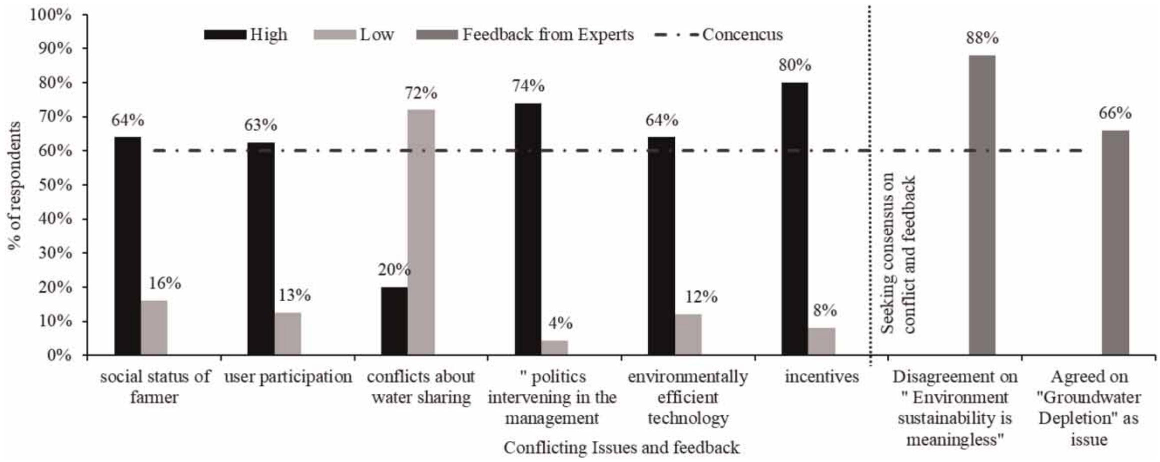


Fig. 8 | Consensus for conflict and feedback obtained in Round-I.

of 'sustainability' in the agricultural water management. The conflicting issues of Round-II met the consensus criteria in the Round-II. Therefore, the survey was terminated after this round.

4. DISCUSSION

4.1. Delphi survey as a tool

The Delphi survey was conducted for a multidisciplinary project consisting of 23 partners from 12 European countries with experts from prominent European water and soil research institutions, research centres, and international experts on stakeholder engagement and communication. Experts working outside the project were also considered to compare and contrast the views. This allowed for the capture of the experiences, knowledge, and presumptions of experts from different fields and geographical locations. Most experts were selected from the case study project itself, and experts outside the case study project were fewer in number. The result showed no significant difference in experts' opinions based on the EU climatic zone but varied when considering the experts outside Europe. The survey lacked gender balance as the experts from the project's case studies were all males. One expert refused to state their gender, stating that gender has no role in this type of research. The self-assessment reflected the expert's knowledge on the topic, meeting the selection criteria of having substantial knowledge on the subject matter. Twelve of the 39 invited experts did not respond to the survey. Most of the non-respondents did not provide any reason for not participating. However, three experts provided reasons based on the boundaries of the survey, giving consent, and the survey covering subjects unrelated to their academic knowledge. There was a single dropout during the survey who did not provide any reason for leaving.

The survey was conducted in three phases: pre-survey, survey, and analysis. In the pre-survey phase, development and evaluation of the questionnaires, and the selection of experts were done. The evaluation of the questionnaire was helpful in guiding the sequence of questions based on the three pillars of sustainability and to spell out the content. The multidisciplinary evaluators provided valuable insights regarding sustainability. Their diverse viewpoints enabled us to identify aspects that may be overlooked if evaluated through a single lens. However, in some cases, the expert evaluation went off track. For example, the evaluators recommended introducing the key concept of 'water stress' into the questions as often-neglected terminology in water management. Upon administration, no expert mentioned this terminology, showing how they did not find it of relevance.

The mean and standard deviation based on relevance, clarity, and sufficiency (Annex C) showed no significant effect on the content of the questions. Instead, it had implications for the question types. Thus, no changes were made to the final questionnaire, but, when conducting surveys in the future, reducing the number of open-ended questions in the survey may be appropriate.

The survey phase was conducted in two rounds, the first collecting the views and the second clarifying the conflicts/comments received in the first round. More than two-thirds of the invitees participated in the survey, but the response rate varied according to the questions. The response rate for the questions related to environmental sustainability was higher than other sustainability pillars. Sending personal feedback with the summary helped increase clarity on the subject matter, and the conflicting issues reached a consensus in Round-II. Thus, further iterations were not required. Regarding the response to providing names for sustainability assessment methods, the majority focused on conventional methods. Still, some experts mentioned using 'degree of satisfaction to the users based on adequacy, reliability, efficiency, and equity for sustainability assessment method', which seems different than the conventional ones.

The experts found the Delphi methodology innovative and an efficient method of collecting various information. However, some experts commented on it as time consuming (Figure 9). The feedback was concentrated on Round-II of the survey, saying that it was hard to comprehend. One reason for this could be that the gap between the two rounds of the survey was high, possibly creating confusion. The major concern to consider is that if the gap between a successive survey round is high, the experts might forget the link between the survey rounds, requiring more explanation and delaying responses.

Delphi surveys support policy making by incorporating different perspectives from various stakeholders, facilitate decision-making by identifying areas of agreement and disagreement, and help resolve complex issues of societal debate through consensus building (Manley, 2013; Mukherjee *et al.*, 2015). A group of 23 experts with diverse academic backgrounds, hailing from both the EU and the global South, were brought together to define SAWM in multidisciplinary settings. Due to the flexibility of methodology, we were able to mix the two different

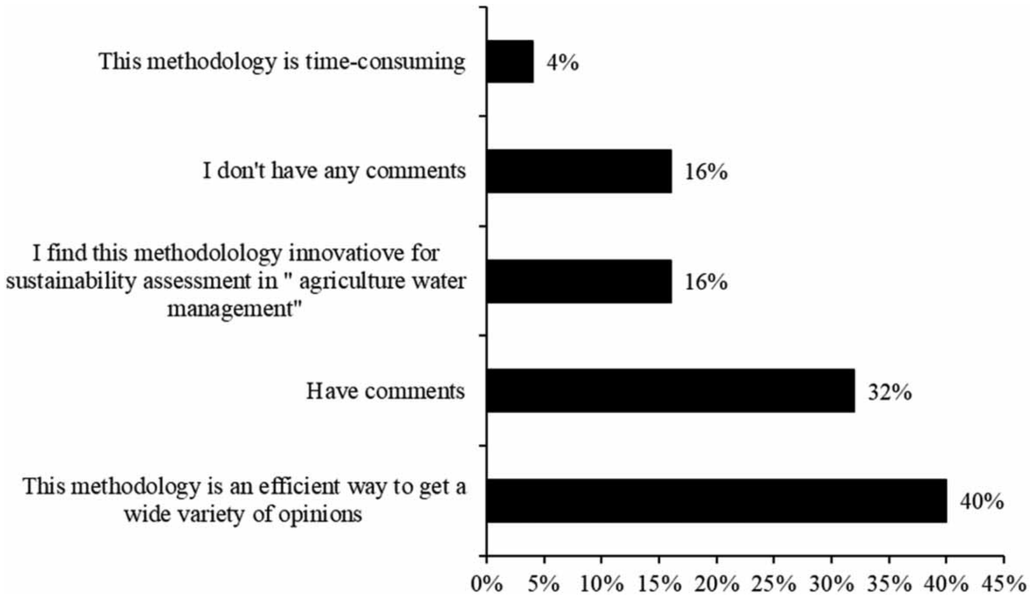


Fig. 9 | Overall feedback on the Delphi survey.

types of Delphi survey methods (decision and policy), which helped us to identify the key concepts and capture the opinion of experts. The key concepts play an important role in conceptualizing SAWM, whereas the various opinions help to enrich the understating of the concepts. The opinion differed in type (stakeholder and consortium members of the projects) as well as the gender of the respondents. For example, experts from the global North focused on water quality, whereas those from the South were concerned with water quantity (further explained in the next section). Thus, by acknowledging and addressing these variations, policymakers can develop more robust, balanced, and effective policies that better align sustainability in water management. In our survey, the participants participated voluntarily, and the response rate was comparatively higher, with almost negligible dropout throughout the process. The experts were able to provide their views on complex topics like 'sustainability' and the feedback round helped the expert to get collective views on their responses. The conflicting views observed in Round-I reached a consensus in Round-II, which is impossible in ordinary surveys. Thus, we conclude that the mix Delphi survey method proves to be a helpful tool for dealing with complex issues such as sustainability.

However, this methodology can also be criticized based on the selection of evaluators and experts, and the type of questions for the survey. The evaluators were asked to review all the questions regardless of their expertise, which made the process lengthy as it required frequent communication in order to generate common/similar views. The process could be simplified by allowing evaluators to focus on their field of expertise instead of evaluating the whole question. Also, the external participants were selected on a recommendation basis, which could create selection bias. The research was focused on obtaining views on the three pillars of sustainability, but most expert's backgrounds were related to the technical/ environmental field. This, therefore, could create 'expert bias' in responding to the questionnaires. Regarding the content of questions, the research consisted of highly theoretical questions that could lead to 'no answering bias', but the responses were high in this research, minimizing this bias. Regarding the sequence of questions, a set of pre-identified concerns were provided, with participants asked to rank them in the order of preference, followed by the open-ended question exploring any concerns in their locality. The concerns were similar to the previous question, possibly due to the 'Response bias' caused by a preoccupied mindset.

4.2. Perception of experts on SAWM

The analysis of sustainable agricultural water management was based on individual responses to the questions related to the general understanding and different thematic profiles of sustainability. The purpose of introducing the questions on 'general understanding of sustainability' in the beginning was to capture the blueprint thinking of experts on SAWM and what they prioritize. Although theoretically, all three sustainability pillars are equally important, the goal of ranking them in relation to SAWM was to gain an understanding of which aspect of sustainability the policy should be prioritized, and which is frequently overlooked by experts. Most experts in this survey mentioned 'environment sustainability' should be the prime focus. This may be the outcome of experts' academic background, as most were technical/engineering personnel. The most frequently mentioned key concepts also focus on environmental sustainability. Thus, having questions from all three pillars of sustainability helped grasp the holistic picture of sustainability from the experts. We also collected the major and minor actors in relation to SAWM. From the result, farmers were identified as the key stakeholders in SAWM. Identifying stakeholders helps streamline the policy regarding who should be considered.

'Climate change' was the most repeated key term by most experts regardless of the theme of sustainability, indicating that it is a significant concern for all categories of expert. Since agriculture consumes an enormous volume of water and occupies a large land area, this concept seems prominent and requires consideration. The concern of climate change is limited not only to water usage and environmental damage but also to people's socio-economic status and livelihood. The other terminology mentioned by the participants from the Global North (consortium members and stakeholders) was 'water quality', which is evident because of the concerns about the contamination of water bodies by diffuse pollution from agriculture (fertilizers/pesticides) in Europe. Concerning water quality, experts also mentioned nutrient runoff, environmental degradation, and pollution of water bodies, which supports experts' concerns. 'Water quantity' is mentioned by experts, especially by external experts (largely from the Global South), throughout the survey, making it another essential piece of terminology. Since water availability is crucial, especially in the Global South, and some places in Europe also face seasonal drought, the identified term carries relevance for the research topic. In support of this terminology, experts have also mentioned protecting water bodies from over-exploitation, meeting the demands of ecological needs, and water balance. Other than the aforementioned keywords on environment sustainability, experts also mentioned 'agriculture' in most places, showing their concern about sustainable water management in agriculture. Concerning agriculture, experts also mentioned farming systems and ecological farming, showing their concern for efficient water use in farming activities. Since most of the experts were inclined towards environmental sustainability and most of the identified keywords were also related to environmental sustainability, further analysis of keywords was done by considering the social and economic aspects of sustainability.

The keywords from social sustainability show that experts from all categories mentioned 'stakeholder participation', implying the need for a participatory approach to water management issues to make it sustainable. It also reflects the idea of water management as a collective action, bringing all stakeholders on board and working together to support the idea of a multi/transdisciplinary approach. Experts from stakeholders and external categories have also mentioned 'Capacity building', which is relevant because various actors have different skill levels. This is necessary for effective communication, understanding each other's ideas and effectively engaging in water management. Participation and capacity building are interrelated because, for the effective involvement of stakeholders in water management activities, there is a need to deploy skills and capacities that are only possible through the enhancement of knowledge. Since 'farmers' were identified as the major stakeholders, their participation and capacity building play a vital role in water management, hence these keywords being significant in the study. However, this terminology was not mentioned by consortium members, possibly because all the consortium members were case study owners and solution providers with substantial expertise in their field. One interesting observation made while analysing the terminologies was that participants from the Global North mentioned 'satisfaction and wellbeing', whereas the participants from the Global South mentioned 'equity' and 'inclusive governance'. This shows the difference in priorities for the same notion of sustainability, which mainly depends upon social constructs.

Regarding economic sustainability, the priority was different for each group of experts. The consortium members prioritized 'economic growth', whereas stakeholders mentioned 'affordable cost' and 'external income and profit'. This shows that the consortium members are groups of experts working on different technologies and measures intended to uplift the overall situation of management practices focused on economic growth. The concern of stakeholders, on the other hand, was about the increasing cost of farm inputs. Concerning sustainable water management in agriculture, the affordable cost is vital because it guides all other components. Expert also repeatedly mentioned 'income and profit generation' in this theme. Since monetary value plays a vital role in agriculture, water management, and sustainability, this term is relevant. Farmers have also mentioned 'subsidies' and 'incentives', which shows their concerns around financial support. The experts from external groups (mostly from the Global South) see farming practices as a rarely profitable profession and provide meaning for the prioritization of income.

In relation to identifying concerns, experts from the Global North mentioned the 'concerns arising from the degradation of watersheds, water resources, and aquatic ecosystems', which shows their focus on conservation of resources, which will eventually have a major role in achieving sustainability. Experts have also shown concerns around ‘Soil nutrition, and overuse of fertilizer’, showing fears for the deteriorating quality of soil health, which also plays a role in water management. The experts from the Global South mentioned the ‘over-exploitation of resources’, showing their concerns on the sustainable use of resources. In the case of social sustainability; however, the issues were different for each expert group. The consortium members focused on the issues of ‘law and legislation, and water rights’. This shows how the expert groups are more focused on systematically implementing management activities at the farm level. The stakeholders, on the other hand, were more concerned about ‘participation’, ‘co-decision making’, and ‘capacity building’, showing their interest in being involved in management activities. The issues are interlinked because, for collective, efficient, and executable decision-making, it is essential to have all the stakeholders onboard and to have sufficient knowledge to understand each other. The external experts mentioned ‘inequitable access to resources’, ‘adaptation to technology’, and ‘complexity in the governance system’. These are mainly related to inequality and the social structure of the individual, geographic area. The issues related to economic sustainability differed based on the type of expert group. The consortium members focused on ‘efficient technology’, reflecting the increasing agro-mechanization and modern technology employed for managing water at the farm level. The low cost of the technology impacts water management as it is easily purchased and can be adopted by farmers. The stakeholders mentioned the issues related to ‘subsidies and incentives’ from authorities focused on supporting farmers’ economic status. The external experts mentioned the ‘farmers’ economic status’, which is directly linked with management aspects through its link to an effective workforce. The survey results also revealed gender differences in the perceptions of sustainable water management. Female experts emphasized ‘water availability’, ‘stakeholder participation’, ‘co-decision making’, and ‘income and affordability’ more often than male experts. It is evident that the various experts have divergent views regarding the prioritization of issues and concerns pertaining to sustainable water management in agriculture. This divergence must be acknowledged when formulating policies.

4.3. Defining ‘sustainability in agricultural water management’

Sustainability is ideal for resource use, considering social, environmental, and economic aspects (Kuhlman & Farrington, 2010). Nevertheless, the question arises of how to define sustainability in a way that best describes the ideal state. The first attempt to define sustainability was from the Brundtland Commission in 1987, which is used as a baseline to define sustainability in agricultural water management in this research.

> ‘… meets the needs of the present without compromising the ability of future generations to….’

Three decades have passed since this definition was coined, but critics claim it to be too vague and, most importantly, to lack consistency (Moore *et al.*, 2017). Furthermore, the synonymous use of ‘Sustainable development’ and ‘sustainability’ has been the subject of contestation from scientific communities (Klauer, 1999). Realizing this complexity, the definition has been narrowed to particular disciplines to ease the operationalization (Tainter, 2003). Various definitions of agricultural water management have evolved based on the scope and objectives of studies/projects. However, according to the study by Dillon *et al.* (2010), the commonality across these definitions is that they all address sustainability’s social, economic, and environmental facets.

If we revisit the definition provided by FAO, The World Bank, or the one from ICID, used at the beginning of this article, we see that all of them cover three major dimensions of sustainability. There is, however, a difference in addressing the subject based on their institutional values. FAO has focused on balancing the cost, quantity, and quality of freshwater with demand. The World Bank prioritizes social dividends, and ICID prioritizes the technological options to ensure sustainability. All of these reflect the institutional values and operational priorities of each institution.

The numerous definitions suggest that sustainability is a subjective concept and contextually defined based on the scope and purpose of the work. This research attempted to define sustainability through a multidisciplinary lens. The definition was created following the 'Purdue Online Writing Lab', which advocates for definitions to consist of the linkages of concepts. Thus, the definition was constructed by considering the most frequently used key concepts (or their closer meanings) from the results. However, the result was influenced by the experts' background, with most experts concerned about 'environmental sustainability'. So, the responses from each theme were considered to provide an acceptable definition that covers all three pillars of sustainability. Since the survey question consisted of many theoretical questions, experts who did not respond were considered to represent a non-response bias due to a view of sustainability as a complex subject, which is hard to comprehend. The average non-response bias for open-ended questionnaires was 23%, which is comparatively low and does not significantly impact the result. Thus, the most repetitive key concepts from all group experts were categorized according to the thematic profiles of questions as shown in Table 3.

Based on these key concepts, sustainability in agriculture water management is defined as follows:

'*Managing water in a way that ensures its quality and has minimal negative effects on the natural environment. It involves stakeholder satisfaction and wellbeing, ensuring equal participation, and improving competency by entailing effective governance and equitable laws. It promotes long-term economic growth and provisions of incentives and subsidies. In summary, it exemplifies the ideal level of water management incorporating climate change concerns.*'

This definition of 'sustainability' determined by the Delphi survey method encompasses all three pillars of sustainability and is in alignment with the famous definition coined by the Brundtland Commission. It addresses the present issues and shows concern for the future. It agrees with the indicators for agricultural water use mentioned in SDG 6, those being water quality, quantity, equitable use and access, and equal participation. This definition is likely to be important when communicating what 'sustainability' means in terms of agriculture water management to those facing operational challenges in multidisciplinary projects. It helps to mainstream sustainable development in policies in the water sector while taking climate change into consideration.

Table 3 | Frequently repeated key concepts.

General definition	Social sustainability	Environmental sustainability	Economic sustainability
• Climate change • Water availability in quantity and quality in time and space • Close to natural water balance • Economically reasonable • Response to climate change • No harm to the environment • Possibility of future regeneration	• Satisfaction and wellbeing • Capacity building • Stakeholder involvement • Fair and unbiased legislation • Inclusive governance • No inequality	• Climate change • Water quality • Ensuring no environmental degradation • Adaption to extreme weather conditions • No harm in terms of water consumption and water quality	• Supports long-term economic growth • Satisfaction with the income generated • Subsidies • Decent working conditions for farmers and job creation in agriculture

5. CONCLUSIONS

A Delphi survey was conducted with 29 experts to better define "sustainability" in the context of agriculture water management. The aim was to improve the communication of solutions for addressing operational challenges in multidisciplinary projects. While viewpoints differed slightly based on backgrounds and thus interests, consensus was reached on major aspects. The survey finding showed that while dealing with SAWM, environmental sustainability and farmers should be in prime focus. Assessing the major issues within each sustainability pillar, experts highlight the following for social sustainability: satisfaction and wellbeing, stakeholder participation, capacity building, and good governance with fair legislation. The major issues for environmental sustainability are water quality, availability, climate change, biodiversity, and maintaining water, soil, and ecosystem services.

Finally, the key concerns for economic sustainability are affordable cost, income/profit generation, subsidies, and incentives. These key concepts were utilized to create a definition of "sustainability" which aligns with the definition coined by the Brundtland Commission. This definition was shared with consortium members of the WATERAGRI project in the regular consortium-wide meetings and used in the respective deliverables dealing with sustainability. The simple fact of carrying out the Delphi survey raised awareness amongst consortium members about their different understandings and viewpoints. The results can further serve as input for conceptual framework development for sustainability as different concepts have been identified, which can be measured using a set of indicators.

The novelty of the current research was its use of expert knowledge to capture the best available information on "sustainability" and define it in the context of agriculture water management. However, this research does not claim to make generic recommendations on SAWM for all audiences and contexts. The study was targeted to a specific H2020 project context and is therefore limited to a low number of experts. Significant efforts were undertaken to find the experts for the study, especially the stakeholders. But the questionnaire was set in English, restricting many stakeholders from being part of the survey. The limited sample size can result in certain stakeholders being favored over others, or even marginalized voices being entirely excluded from expressing their views. Lastly, due to anonymity, communication with an individual expert to clarify any issues took time, delaying the process. Nonetheless, based on these limited findings, one recommendation to be drawn from this work for broader policy formulation for SAWM in Europe is to prioritize farmer needs and to focus on environmental sustainability. The conflicting concerns between experts' and stakeholders' needs, such as highlighting the importance of developing low-cost technologies versus equal participation in the decision-making process, should be carefully considered while formulating the policies. Similarly, diverging concerns between the limited set of participants from the Global South shows that priorities may not always align. While experts from the Global North focused on water quality, well-being, and subsidies, those from the Global South mentioned water quantity, good governance, and income generation. In the future, similar research could be conducted by considering a significantly higher number of experts from different parts of the world. The questionnaire structure could be changed to a more measurable format by reducing the number of open-ended questions, helping retain experts through consecutive rounds. The study can be replicated in other parts of the world as its use of key concepts creates a widely accepted definition of SAWM for all types of trans/multidisciplinary projects and therefore provides more meaningful policy recommendations.

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DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

The authors declare there is no conflict.

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