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A Study on Water Markets and the International Experience Gained from their Establishment

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Water markets are considered an excellent economic instrument for water management as they lead to a more efficient allocation and use of the resource. Their establishment and operation has been promoted due to the fact that the steadily increasing demand is creating water scarcity problems in many regions of the world and that existing management policies are proving ineffective in addressing modern challenges. This paper attempts to carry out a comprehensive review of water markets as an alternative method for water management by presenting their main characteristics as well as the international experience gained from their establishment in different regions of the world. For this purpose, a systematic review of the international literature in the Google Scholar and Scopus databases was carried out using specific criteria. In particular, 144 studies were found that met the search criteria set and finally 91 of them were selected as a source of information for the writing of this paper. The processing of these papers provided information on how water markets operate, their background, the advantages and disadvantages associated with their establishment and their adoption by countries with different characteristics. The main conclusions that emerge are that water markets on the one hand increase the economic efficiency of water by encouraging the movement of water quantities to users who are able to attribute to them high economic value and on the other hand that their establishment and operation are linked to neoliberal economic policies that are often criticised and at the same time raise issues of social justice and equal treatment of different users.

Keywords: water resources management, water markets, tradable water rights, water trading.

Introduction

In recent years, the rapid economic development in many regions of the world combined with population growth, improved living standards and changes in people's lifestyle have significantly increased the demand for water and consequently created water scarcity-related problems in many regions (Borghesi, 2014; Debaere, 2014). As it is estimated by the World Health Organization, within a few years almost half of the world's population will live in water-stressed regions, and nowadays almost 844 million people do not have access to drinkable water (Wutich et al., 2020).

These pressures are significantly intensified by climate change and the inefficient and unsustainable way many countries manage water, forcing changes in the way different countries allocate limited water resources among different users (Koopman et al., 2017; Walter et al., 2010). In this context, existing water resource management systems, which are based on treating water as a social-public good, are proving increasingly ineffective, creating serious risks for local communities and economies (Debaere et al., 2014; Bekchanov et al., 2013).

Considering the above, many countries are undertaking reforms related to how water is managed and allocated by modifying both the relevant legislation and common practice (Rey et al., 2019). The relevant policies implemented can be broadly divided into two categories: those aimed at improving supply, such as the construction of new infrastructure, and those aimed at managing demand (Aghaie et al., 2020). As policies aimed at improving supply appear increasingly less able to address the problems associated with water scarcity in many regions of the world, policies and related reforms aimed at demand management appear to be the most viable solution (Bekchanov et al., 2015).

Policies and related reforms aiming at demand management have a focus on treating water as an economic good (Bjornlund and McKay, 2002). Treating water as an economic good is based on three assumptions concerning it, which are the following: first, water is a finite natural resource and thus it has an economic value; second, the provision of the necessary quantities of water to humans for their various activities requires the construction and operation of costly facilities that require financial resources which can only be secured through water charging in order to operate properly; third, the limited availability of water makes it necessary to effectively manage the demand by maximizing the benefit derived from water (Tsiarapas and Mallios, 2020; Lubell and Edelenbos, 2013; Biswas, 2008).

This approach was first presented at the United Nations Conference on Environment and Development held in Rio de Janeiro in 1992 and came as a result of the formulation of the *Dublin Principles for Water* (formulated as a result of the International Conference on Water and the Environment held in Dublin in 1992), one of which recognises the economic value of water and urges that it should be treated as an economic good (Hodgson, 2006). This fact combined with the subsequent publication of the Directive 2000/60 EC by the European Union which recognises water not only as a fundamental social good but also as an economic good paved the way for a new planning for water resources management.

That being the case, there is a growing interest in the role that economic instruments such as water markets can play in improving and facilitating water resources management and allocation (Walter et al., 2010; Rey et al., 2019). Water markets are considered an excellent instrument for demand management and water reallocation in areas facing water scarcity, i.e. areas where there is increasing demand while availability is limited (Seidi et al., 2020; Easter et al., 1999). What water markets do is lead to an efficient allocation of water to different users by balancing the forces of supply and demand, and therefore it is considered that they can provide sufficient quantities of water for urban, industrial and agricultural use without the need for new costly infrastructure (Mattheis et al., 2009; Hearne and Easter, 1997). Hence, the establishment and operation of such markets is a strategy to improve water efficiency and is promoted to a significant extent by both the irrational and inefficient use of this precious resource by many countries and the gradual adoption of neoliberal economic policies over the last decades (Campanhao et al., 2021).

This paper attempts, through a systematic review of the international literature, to present first the main features of water markets, the theoretical background behind them, how they operate, their main categories, the advantages and disadvantages associated with their establishment and operation and then the experience gained from the establishment of water markets in different regions of the world. These are consequently the research questions that this paper seeks to answer. This work differs from similar works appearing in the international literature in that it presents an overview of water markets that includes the entire theoretical context about them, it seeks to answer the majority of the questions raised about them, and it refers to the overall international experience gained from their implementation without focusing on a specific geographical area. Thus, the novelty of this review lies in the fact that it is not just another study concerning water markets and their implementation in specific countries but a complete work that can be used as a useful guide for scholars dealing with water markets and seeking to answer theoretical questions about them.

Methods

The methodology followed for writing this paper was that of a systematic literature review. This methodology was chosen as it was deemed to be the most appropriate to answer the research questions of the paper as outlined in the introduction.

A paper that is the product of a systematic literature review is essentially a summary of the available literature on a topic. The author of a systematic literature review is not limited to simply reading existing research on the topic of interest but extends to critically analysing it in order to evaluate it and ultimately produce a result that contributes to the existing knowledge on the topic under study (Landa et al., 2011). The reasons that lead to the decision to conduct a systematic literature review may be the desire to summarise prevailing views on a topic, or the advantages and disadvantages of a method of analysis, or even to find the research gaps that exist in a research topic. The stages that make up such a research are three and include designing the research, conducting the research and publishing it (Busalim and Hussin, 2016). During the stage of designing the research, those parameters that will be used in order to limit the research have to be determined. These include the language of the sources to be used, the geographical area from which information will be sought, the period of publication of the sources and of course the type of sources which can be scientific articles, conference proceedings, books, etc. (Zafeiriou, 2019). In conducting the research, bibliographic sources – mainly scientific articles – are searched mainly in electronic databases using keywords and using the AND, OR, NOT operators to facilitate the search. The search is also continued in sources listed as references to the bibliographic sources that resulted from the initial search (Patelarou and Mprokalaki, 2010).

The main ingredient of success of this methodology is the selection of appropriate literature sources that are relevant to the topic and can answer the research questions posed. The general concept of the systematic literature review methodology is illustrated in *Fig. 1*, which depicts the flowchart of the literature search process.

The first step required to apply this methodology is to define the parameters of the research. The research parameters are presented in *Table 1*. As it can be seen in *Table 1*, the databases that were selected were Google Scholar and Scopus, the keywords selected were "water markets", "water trading" and "tradable water rights" and the studies' continent of origin (geographical area) was selected not to be limited. The selection of the keywords shown in Table 1 was made with the aim of limiting the search as much as possible. Thus, no keywords were chosen as keywords that might be implicitly related to water markets such as "water economics" or "economic instruments" AND "water resources management", where AND is the well-known Boolean operator.

Table 1. *Parameters associated with the searching process*

Parameter	Which/When
Databases	Google Scholar, Scopus
Keywords	"water markets" "water trading" "tradable water rights"
Studies' continent of origin	All continents
Time period of the searching process	11th January 2021 – 16th February 2021

Fig. 1. *Flowchart that elaborates the workflow of the searching process (Source: own work)*

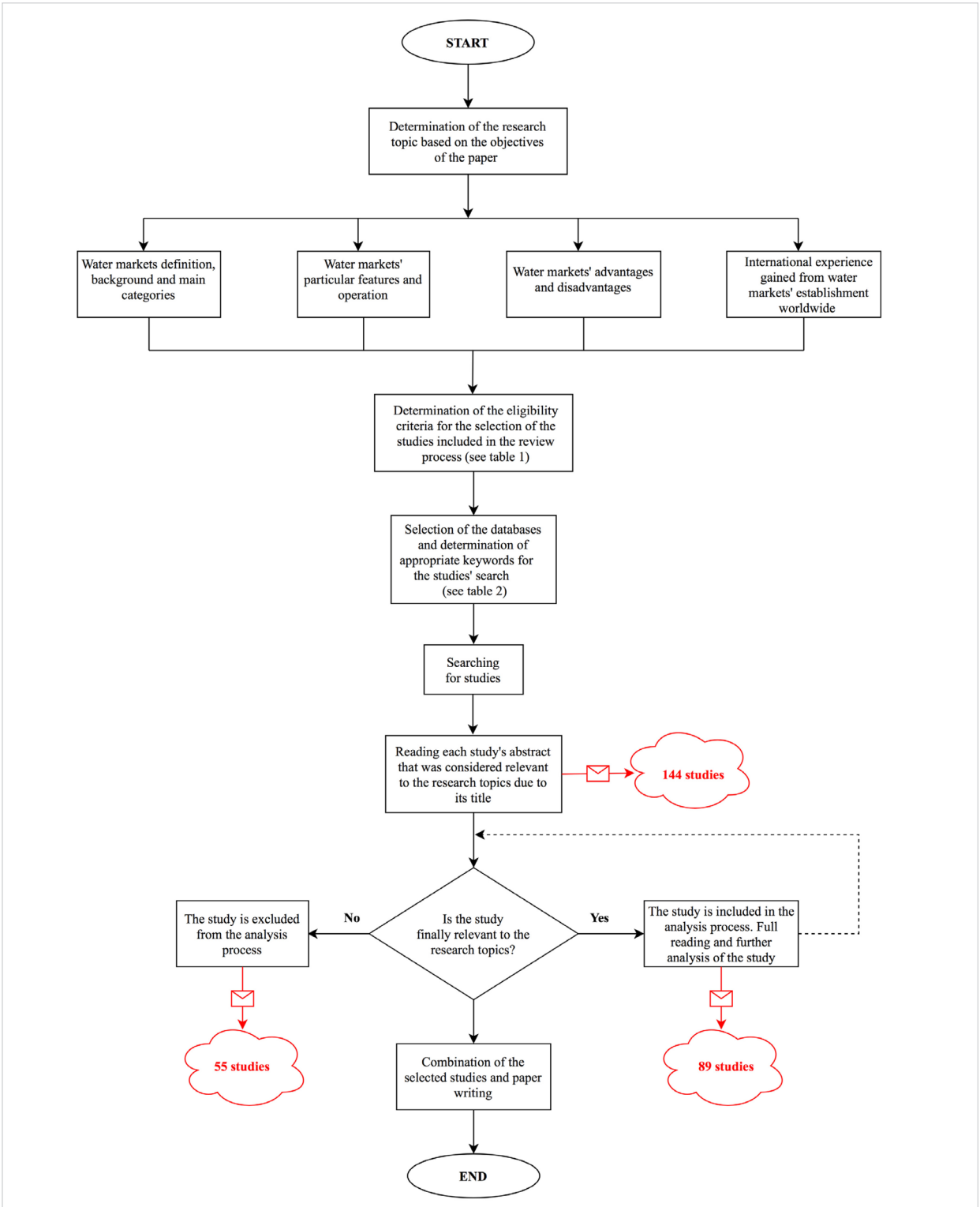


Table 2 summarises the eligibility criteria for selecting or rejecting a study. Due to the fact that water markets are not a new concept as they have appeared in the international literature for some decades, it was decided not to set time constraints in the search for literature sources and it was also decided not to set geographical constraints, as it was mentioned above, since water markets have been established in many regions of the world.

Table 2. *Eligibility criteria for the selection of studies included in the literature review process*

Criterion description	Studies included
Document type	Journal article, book chapters, conference papers, reports, PhD and Master theses
Type of study	Qualitative and quantitative
Publication date	No limit
Language	English
Availability	Online full-text availability (through institutional access)
Geographical origin	No limit

Results and Discussion

The following lines present the findings of the systematic literature review conducted on the basis of the parameters mentioned above. First, some statistics about the literature sources used are presented and then the qualitative results of the research are presented.

The results of the search based on these parameters are presented distributed in time intervals in *Tables 3* and 4 and in *Figs. 2* and 3, respectively. Both from the data in these two tables (2 and 3) and from *Figs. 2* and 3, two conclusions can be drawn: firstly, that research interest in water markets has increased significantly over the last twenty years with a large number of papers published every five years, and secondly, that the number of published papers is large and therefore it is impractical for a researcher to study all these papers, so that the definition of criteria for the acceptance of papers is required in order to limit the volume of study.

Table 3. *Results obtained from the searching process in Google Scholar database*

Google Scholar			
	"water markets"	"water trading"	"tradable water rights"
until 1980	136	41	4
1981–1985	101	17	0
1986–1990	339	46	1
1991–1995	749	105	54
1996–2000	1580	400	278
2001–2005	3030	1090	473
2006–2010	4270	1990	520
2011–2015	5280	2500	496
2016–2021	5710	2820	494

Table 4. *Results obtained from the searching process in Scopus database*

Scopus			
	"water markets"	"water trading"	"tradable water rights"
until 1980	4	0	0
1981–1985	6	0	0
1986–1990	36	1	0
1991–1995	46	9	4
1996–2000	85	12	7
2001–2005	201	41	7
2006–2010	270	76	11
2011–2015	321	113	13
2016–2021	360	95	10

The application of the criteria described in Table 2 led to the limitation of the search as 144 studies were found that met the specific criteria and were considered relevant to the topic of the paper. After reading the abstracts of these studies, 91 of them were selected and studied in detail, the detailed description of which is presented in Table A-1 (see Appendix). These 91 studies were the sources of information for the drafting of the paper. The majority of these studies

are papers published in peer-reviewed journals as shown in *Fig. 4*. Further on, *Fig. 5* shows the distribution of the 91 studies by the continent from which the authors come from. In the case of the reports, the continent of origin was considered to be the continent where the headquarters of the issuing organisation or government is located. As it can be seen, more than half of the studies originate from the Americas or Europe. Finally, *Fig. 6* shows the distribution of the studies by date of publication. As it can be seen, this graph follows the trend that graphs presented in *Figs. 2* and 3 also follow and which concerns a steadily increasing number of studies related to water markets published in the course of time.

It should be noted that in addition to the studies directly related to water markets, studies not directly related to water markets were used to flesh out the part concerning the background of water markets. These studies are not included in the 91 studies for which the relevant bibliometric analysis is presented.

Fig. 2. *Graph that corresponds to data provided in Table 3*

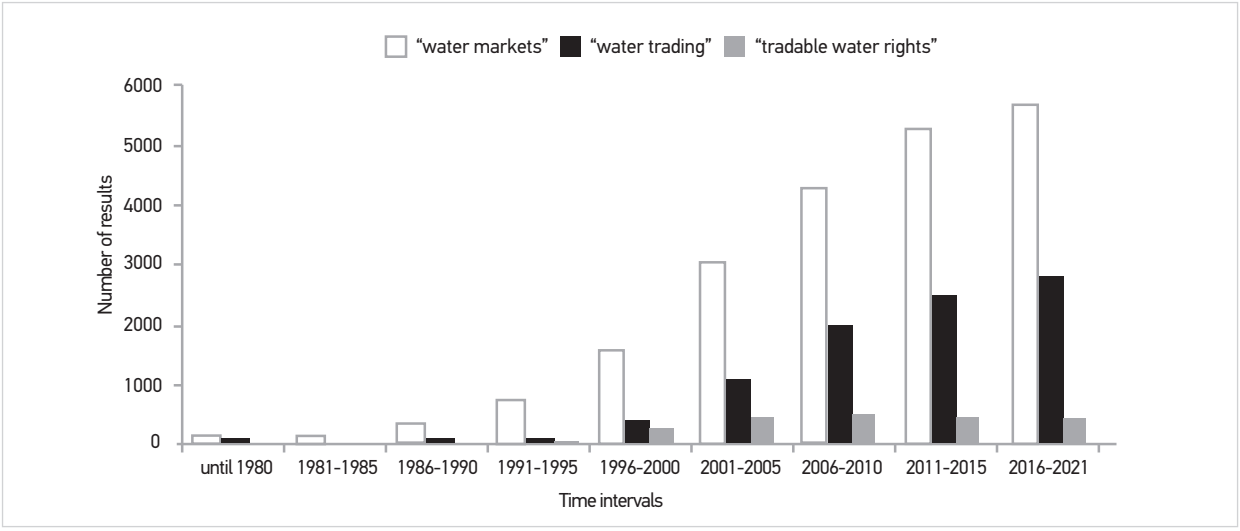


Fig. 3. *Graph that corresponds to data provided in Table 3*

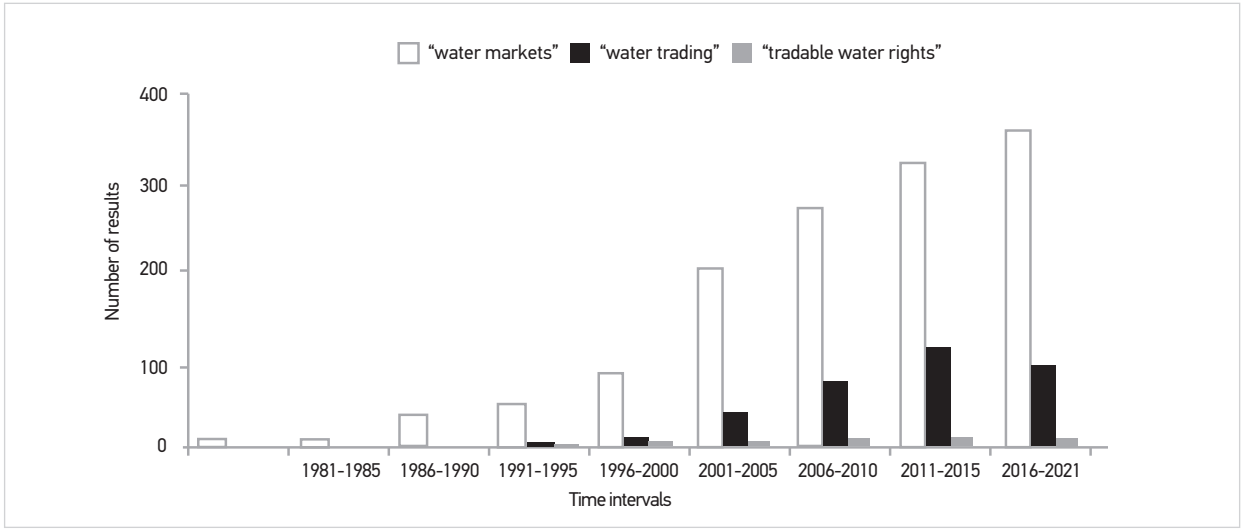


Fig. 4. *Document type and percentage per document type of the studies included in the literature review*

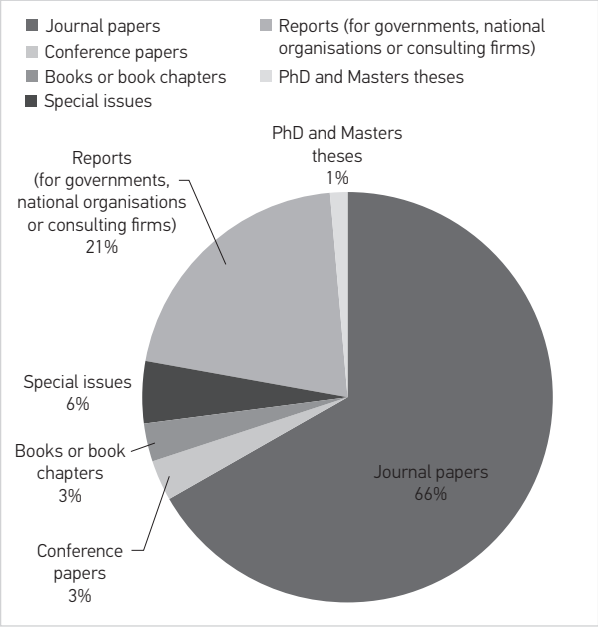


Fig. 5. *Continent of origin and percentage per continent of origin of the studies included in the literature review*

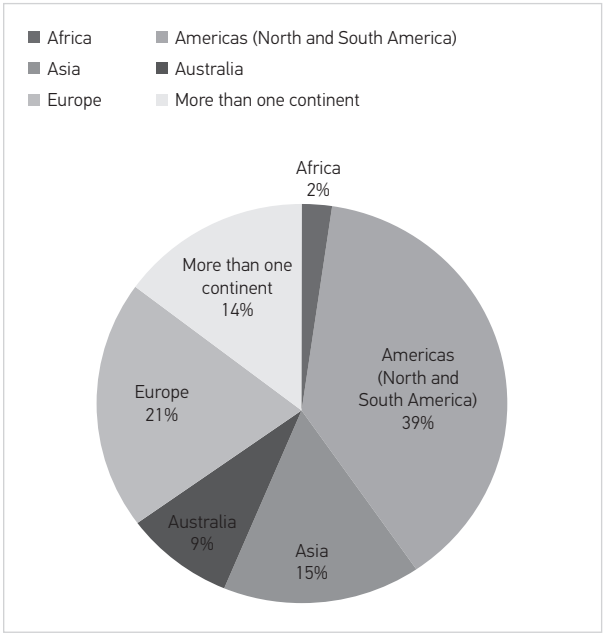
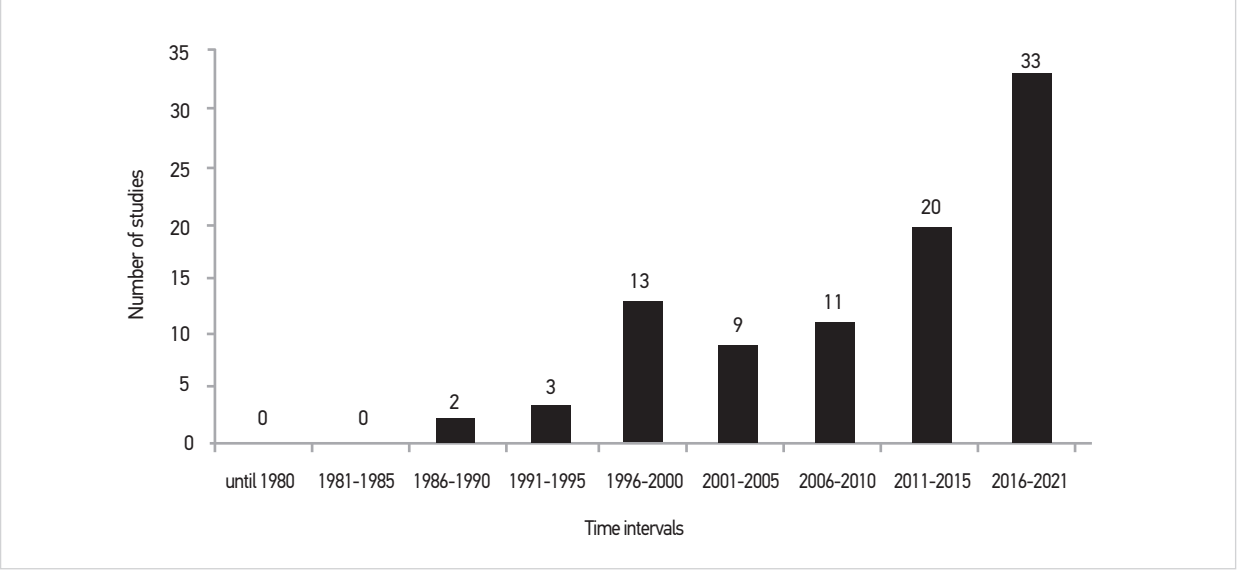


Fig. 6. *Date of publication of the 91 studies included in the literature review*



Water markets' definition, background and categories. One of the first questions one might ask is what exactly a water market is, what is the scientific background behind water markets and which are the categories of water markets that exist around the world. This section aims to provide a brief answer to these questions.

Water markets' definition

A water market can be defined as an institutional framework of legal or social principles that allows some users – water rights holders – to transfer these rights to other users – also rights holders or not – against a financial compensation based on certain rules (Rey et al., 2019). Water rights have the role of currency in a water market and it should be noted that they are in most cases use rights and are in no way linked to the ownership of water as a natural resource (Richter, 2016). In other words, a water market is a system of formally institutionalized and/or informal regulations and controls that govern the purchase and sale of water rights (Debaere et al., 2014). Therefore, in reality what constitutes a water market are the transactions and interactions between buyers and sellers with the market itself being a legal or social institution that simply aims to facilitate these transactions (Lee and Jouravlev, 1998). This institutional framework, which essentially allows water trade among different users, can exist both at the level of a small sub-basin and at the level of an entire basin (Bekchanov et al., 2013).

Water markets' background: the Coase theorem

The idea of implementing tradable rights for the allocation of natural resources and consequently water markets is attributed to the Canadian economist John Dales, who formulated his proposal based on the Coase theorem (Borghesi, 2014). Although the Coase theorem has been formulated since 1959, the first formal formulation came in 1966 by George Stigler and since then many other alternative formulations have followed (Medema and Zerbe, 1999). According to Stigler (1966), what the Coase theorem argues is that under conditions of perfect competition, social and private costs will be equal. A more careful and explicit formulation of course is that presented later by Regan (1972), who stated that"... in a world of perfect competition, perfect information, and zero transaction costs, the allocation of resources in the economy will be efficient and will be unaffected by legal rules regarding the initial impact of costs resulting from externalities." Therefore, according to Coase, it is the market that will provide the socially optimal solution to a natural resource allocation problem, so the crucial step in maximising the social benefit of a natural resource, such as water, is simply the fact that a relative market exists and rights of use are allocated regardless of how this allocation is carried out (Raffensperger and Milke, 2017). This assumption has been incorporated into modern economic theory, which argues that under ideal conditions the trading of a natural resource can lead to the socially optimal allocation of that resource regardless of how it is initially allocated to users (Chong and Sunding, 2006).

From the above, it can be understood that the key assumptions, i.e., ideal conditions on which the Coase theorem, and by extension the theoretical, economic understanding of the problem of optimal allocation of natural resources, is founded are (Raffensperger and Milke, 2017; Hadjigeorgalis, 2009; Hoffman and Spitzer, 1982):

- first, that natural resource use rights are well defined,
- second, that there are no transaction costs in transferring the rights from one user to another,
- third, that there is perfect information,
- fourth, that perfect competition prevails in the relevant market; and
- fifth, that in any negotiation for the transfer of rights to use the resource there are two parties involved – a buyer and a seller – who seek to maximise their profit and the utility they derive from the resource.

Of these assumptions, the most important is the one related to zero transaction costs. This is an assumption that is considered as unrealistic (Coase, 1960), since in the case of water, transaction costs not only exist (Hadjigeorgalis, 2009) but are also very high. Thus, views have recently begun to develop that argue that the Coase theorem cannot apply to water, with that of Nobel Prize-winning economist Eric Maskin leading (Raffensperger and Milke, 2017).

In summary, what should be noted is that regardless of the Coase theorem, the basic idea underlying the tradable rights system and thus water markets is to use the properties of markets as tools to optimally allocate natural resources in order to both achieve economic efficiency and avoid overexploitation of these resources (Borghesi, 2014). More specifically and in

the case of water markets, it is assumed that in a fully competitive market these water rights will end up with those users who can attribute the highest possible value to the resource (Kraemer et al., 2004).

Types of water rights

As understood from the definition of water markets presented, the most basic parameters associated with them are water rights and the water transactions that take place among users. The big question that arises here is what exactly these rights are, what categories of rights exist and, correspondingly, what categories of transactions exist.

Water rights are usually defined in terms of volume (for example, in cubic metres or litres/second) or as a share of the flow in a canal or stream, or in terms of time during which a particular water supply inlet is accessible to a particular user (Holden and Thobani, 1996). This essentially means that water rights are either quantities of water expressed in units of volume or percentages of a particular flow or hours of use.

In general, water rights can be divided into three categories (Colby, 1988; Holden and Thobani, 1996; Meran *et al*., 2021):

- those based on the riparian rights system (riparian rights). In this case, any landowner adjacent to a river can take water from the river provided that some water is left for other landowners along the river's course.
- those based on the prior rights system. In this case, water rights are allocated to users on a first-come, first-served basis, which means that, for example, in the case of a river, those users who are first in line along the river's course can take as much water as they want from the river without concern for subsequent users, who in times of drought may be left without water. To address this problem when water rights are allocated under this system, a distinction is made between consumptive rights (the holders of these rights have no obligation to return water to the river) and non-consumptive rights (the holders of these rights have an obligation to return water of a certain quality and quantity to the river).
- those based on the public allocation system. In this case, which is the most commonly used when establishing water markets, the allocation of water is determined by the public authorities, which allocate water rights to users with or without charge, but impose charges for the use of the resource. In particular, the water available in a region is divided into a consumptive pool and an environmental pool, i.e., water that is not to be consumed. A share of the consumptive water is allocated to each user and is called a water entitlement and expresses a perpetual right of access to water as a percentage of the total consumptive water available per period. Water entitlement transactions based on the public allocation system can be divided into temporary and permanent. In the case of temporary transactions, a user holding a water entitlement for a certain quantity leases a part of this entitlement for a certain period of time (in many cases even for a few hours) to another user without transferring ownership of the entitlement. In contrast, in the case of permanent transactions, ownership of the right is transferred for a long period of time (at least equal to a period) (Hearne and Easter, 1997; Delorit and Block, 2018).

Formal and informal water markets

Water markets can be divided according to the legal status that governs their operation into two categories: formal and informal (Hadjigeorgalis, 2009). This distinction, which is the most basic one, is based on two different views on the institutional environment required for the efficient operation of a water market: the neoclassical view, which argues that a formal institutionalised system is required for the operation of a water market, and the practical or pragmatic view, which argues for the importance of promoting informal agreements between different users (Easter et al., 1999).

Formal markets are those that are supported by a legal system that facilitates water rights transactions and the corresponding contracts signed between users while protecting the interests of all stakeholders involved. Moreover, in a formal water market, the transfer of user rights is usually long term which makes the impact of the market on the community quite high (Bjornlund and McKay, 2002; Matchaya et al., 2019). The success of a formal water market largely depends on the legal framework governing it and their establishment is appropriate in areas where water rights transactions between users belonging

to different sectors of the economy are needed (Hadjigeorgalis, 2009). Under ideal conditions in a formal water market, both the price a user pays for the use of a given quantity of water and the other terms and conditions related to the transaction are exclusively negotiated between the seller and the buyer. However, in a formal water market, there are usually restrictions imposed by a central authority (Holden and Thobani, 1996). Formal water markets are the ones studied in this paper and will therefore be discussed in more detail below.

Informal markets are those in which agreements are made between users based on social imperatives rather than a legal framework. The operational framework of informal water markets is largely determined by the needs of the users (Hadjigeorgalis, 2009). In informal water markets, the transfer of water rights is usually temporary which makes them preferable for users as they do not actually change the "ownership" of water rights (Bjornlund and McKay, 2002). Here the sale prices of water rights are freely negotiated between the seller and the buyer and the lack of a legal framework governing the transactions limits the application of such markets to users belonging to the same sector of the economy, such as the sale of a certain amount of water by one farmer to another who owns a neighbouring parcel of land (Holden and Thobani, 1996; Thobani, 1997). In general, informal water markets have been established in areas where governments have failed to address water-related challenges. Although they are illegal, governments often overlook this fact as they believe that informal markets achieve rapid and efficient water reallocation (Thobani, 1997).

Table 5 summarises the main features of formal and informal water markets.

Table 5. *Main features of formal and informal water markets (Source: own work)*

Formal water markets	Informal water markets
There is a legal system governing the transactions	They are based on social imperatives and users' needs
There is a central authority that controls the transactions and regulates the relevant terms	The terms of each transaction are freely negotiated between the seller and the buyer
Long-term transfer of water rights	Temporary transfer of water rights
Suitable for water transfers between users in different sectors of the economy	Suitable for water transfers between users in the same economic sector
They are legal	They are illegal

Decentralised and centralised markets

Another distinction of water markets found in the international literature is that between decentralised and centralised water markets, which is made on the basis of the structure of the markets. In the first category of water markets, buyers and sellers trade directly with each other without the mediation of a broker. In this case, prices are set by the market itself through continuous interactions between buyers and sellers. In the second category, also called the "smart market", water allocation is based on the willingness to pay (WTP) and willingness to accept (WTA) of market participants through a double auction mechanism implemented by a central authority that receives bids from both buyers and sellers concerning the water quantities they want to buy and sell respectively and the corresponding prices they are willing to pay or accept as compensation (Xu et al., 2018). A special category of centralised water markets are water banks, which are essentially market mechanisms through which an administrative body, private or state-controlled, acts as an intermediary when trading water quantities in order to facilitate and provide information to traders (Montilla-Lopez et al., 2016). Decentralised markets are considered more flexible in contrast to centralised markets which are considered slower and cumbersome as they often require bureaucratic procedures to operate (Hill and Tollefson, 1996).

Formal water markets: particular features and operation

As mentioned above, this paper primarily deals with formal water markets. Therefore, this section presents both the particular features that distinguish formal water markets from other water allocation methods and a brief description of how they operate.

Formal water markets' particular features

The particular features that distinguish a formal water market from other methods of water allocation to competing users or more correctly from other processes of transferring water from one user to another can be summarised in the following three points (Colby, 1988; Lee and Jouravlev, 1998):

- Tradable water rights, i.e., the quantities of water that are the subject of a transaction in a formal water market, have a separate value from both that of the services required for the transaction and that of the land that may contain them. This means that for a formal water market, water is an economic entity in its own right.
- The driving force of a formal water market is the perception among the various users and potential buyers or sellers that water rights transactions work to their benefit and therefore the reallocation of water that follows each transaction can be seen to have the consent of the transactors.
- No central authority determines the price or any other term of a water rights transaction carried out in the context of a formal water market. What a central authority can do is to impose a framework of rules within which a formal water market operates. This means, on the one hand, that both the price and the other terms governing each transaction are negotiated between the buyer and the seller and, on the other hand, that each transaction can be financially profitable for the seller since the seller is not bound to sell at cost.

Formal water markets' operation

From the above it is clear that water allocation through a formal water market is directly linked to the establishment of tradable water rights (Bekchanov et al., 2013). What should be noted is that water rights exist in many countries. What formal water markets seek to do is either restructure or modify existing systems towards economic efficiency (Rosegrant and Binswanger, 1994).

The operation of a formal water market consists of the initial allocation of water rights and the trading of rights among users. For this reason, a formal water market is divided into two sub-markets, the primary and the secondary market (Wang et al., 2019). This means that a central authority with a role similar to the one described above first sets a water consumption cap for each user that corresponds to the maximum amount of water that the user can consume (Borghesi, 2014). This process which is called initial allocation of water rights or primary water market (Wang et al., 2019) is one of the most important parameters for a formal water market, as it is considered to be a focus for intensifying competition among users. For this reason, the primary allocation should be fair or at least perceived as such by users. The initial allocation can be carried out in several ways which are as follows (Tietenberg, 2006; Armitage et al., 1999):

- based on historical data on water use by each user,
- in a random way, i.e., by the organisation of some kind of lottery by the central authority regulating the official water market,
- based on queuing theory, i.e., based on the principle that the first user to apply for water rights is served first (also known as first-come first-served),
- based on specific rules imposed by the central authority which determine a user's eligibility to participate in the process, and
- through auctions in which different users are invited to participate.

Once the above process is completed, users have the possibility to either buy or sell these rights according to their water needs (Borghesi, 2014). More specifically, after the initial allocation of water rights, these rights can be transferred from one user to another through trading. This marks the transition of the formal water market into a second phase, also called the secondary water market (Wang et al., 2019).

Transaction costs

As mentioned in the relevant section, a key assumption of the Coase theorem on which the concept of natural resources' markets is essentially based is that of zero transaction costs. This assumption, of course, is not realistic as in the case of water markets transaction costs are not equal to zero and are the cause of the operational difficulties that often occur in them (Wang, 2012). The operation of a formal water market is therefore largely constrained by transaction costs, which when high can lead to a reduction in the volume of transactions among

users and thus limit the positive economic impact of formal water markets (Armitage et al., 1999).

In general, transaction costs are those costs associated with the establishment, operation and promotion of a formal water market and are incurred not only by stakeholders involved in a transaction but also by the public sector and relate to both primary and secondary market. The existence of transaction costs is felt by participants in a formal water market through the imposition of fees and taxes on the transactions that take place (Lee and Jouravlev, 1998; Armitage *et al*., 1999).

The activities that are the source of transaction costs are three: search and information, negotiation, contract signing and decision making, and supervision, monitoring and promotion (Lee and Jouravlev, 1998). In particular, transaction costs include (Armitage et al., 1999; Rosegrant and Binswanger, 1994; Hearne and Easter, 1997):

- The cost of opportunity identification, i.e., transactions that may prove profitable or otherwise buyers and sellers willing to enter into a transaction.
- The cost of negotiations preceding the transaction in the secondary market or the cost of the central authority in deciding on the initial allocation of water rights in the primary market.
- The costs associated with bureaucratic procedures involving the validation of a transaction.

The costs of monitoring, limiting or even eliminating the influence of externalities on transactions. Externalities in the context of a formal water market can be defined as the effects of a water rights transaction on a third party that is distinct from the seller and the buyer, i.e., not directly involved in the transaction (Raffensperger and Milke, 2017).

The cost of the infrastructure used to transport water to users, the associated treatment that may be required and the monitoring of this process.

Conditions for an effective formal water market

There are certain criteria that have to be met in order for water to be efficiently allocated to users through a market. In this section, those conditions that are capable of ensuring the existence of a functional and efficient market are to be presented.

In general, the proper operation of any market requires firstly that no user has the ability to control and determine the price of the traded good, secondly that the market is monitored by an authority that enforces rules and thirdly that transaction costs are low (Raffensperger and Milke, 2017). When these conditions do not apply, the market is not only not efficient but is driven to failure.

The proper and efficient operation of any market, therefore, requires the existence of certain conditions. These conditions for the case of water markets are those presented below (Lee and Jouravlev, 1998; Simpson and Ringkog, 1997; Armitage et al., 1999; Kraemer et al., 2004; Dinar et al., 1997; Bekchanov et al., 2013; Holden and Thobani, 1996; Rosegrant et al., 1995; Hung et al., 2014):

- There must be a physical and legal possibility for a water market to exist.
- The product that is traded in each market must be identifiable. In the case of formal water markets, this means that water rights must be clearly defined in terms of ownership and measurable and fully differentiated from land tenure. This condition is the most important prerequisite for the effective functioning of a water market (Wheeler et al., 2020).
- Demand for water must exceed supply so that competition among users occurs.
- There must be information on the supply and demand for water.
- The quantities of water corresponding to the water rights that are in turn subject to negotiation must be available to buyers at the place and time they need them.
- There must be a strong legal and organisational framework governing the market, which ensures that:
  - prospective buyers feel confident that they will ultimately be able to use the water supplies they have acquired and derive the benefits they expect from them,
  - problems arising between market participants are resolved,
  - all users will have water both during periods of surplus and during periods of shortage,

- users are adequately compensated when they transfer the water rights granted to them,
- the right conditions are not created for a monopolistic market to develop,
- environmental laws are respected and
- all stakeholders involved participate in shaping this framework.

_ The water market must take into account the social and cultural dimensions of water. This means that the way the market operates must be compatible with the social and cultural values of the area where it is established.

_ The water market must be economically sustainable in the long term.

_ The initial allocation of water rights and the way in which this is done must be clearly defined.

_ Investments should be made in infrastructure to ensure the safe transfer of water from one user – the seller – to another user – the buyer.

Advantages and disadvantages of water markets

Advantages

Public policy experts on water in every country and prominent academics and economists around the world have increased expectations of water markets. These heightened expectations are based on an anticipated development since the establishment of water markets and a core belief behind it. The expected development is the provision of incentives for more efficient use of water. This means that users who cannot add much value to water will have an incentive to sell their allocated rights to other users who are able to add more value to water. The basic belief is that reallocating water through a market reduces government spending on new infrastructure since the demand for water is reduced, while the possibility of assigning the operation of water markets exclusively to the private sector can further reduce central government spending on the maintenance of existing infrastructure (Bjornlund and McKay, 2002).

More specifically, the benefits of establishing water markets can be summarized in the following points (Rosegrant and Binswanger, 1994; Rosegrant et al., 1995; Bekchanov et al., 2013; Armitage et al., 1999; Howe et al., 1986; Bonnis et al., 2011; Dinar et al., 1997; Holden and Thobani, 1996):

_ Water markets offer a great deal of flexibility to market participants in terms of the price at which they procure water and, in the case of farmers, the price at which they sell their products. This means that when a user considers that the price asked by another user for the sale of water rights is high, he can seek another seller who will offer a lower price. In the case of farmers, they are given the option to change crops when they consider a particular crop to be more profitable, regardless of how water-intensive it is, as there is no question of water supply.

_ The position of users is strengthened as the reallocation of water through a market is a process in which their interests are taken into account, which is particularly the case in the initial allocation of water rights, and financial compensation is provided for those users who transfer their water rights to others.

_ It increases users' security of tenure of their water rights as no user is obliged to transfer their rights to others.

_ Incentives are created to adopt water-saving techniques, since the water saved can be a source of additional income for the users.

_ Users are offered the possibility to obtain additional economic benefits by selling part of the water rights originally granted to them.

_ It enables mainly professional users (industry and farmers) to re-evaluate the profitability of their activities as the establishment of the water market opens up new business opportunities for them through the sale of water rights which may be more profitable than their main activity. In other words, users are induced to take into account their opportunity costs.

_ Water markets are more acceptable to users both compared with other water allocation methods and compared with traditional water pricing methods. This is due to the fact that transactions through a water market guarantee a climate of fairness as if someone considers that they do not have an interest in the purchase and sale of water rights, they may simply not participate in the market.

- Water markets are generally considered to reduce the information costs of the central authority responsible for water management, as the information required is now generated by the market itself and the users bear the corresponding costs.
- Environmental protection is enhanced as the shift towards more efficient water management implied by the establishment of a water market is considered to reduce the pollution associated with irrigation water.

Disadvantages

Despite the multiple benefits of establishing water markets, there are factors that can be an obstacle to their effective operation. These factors are mainly related to the specific physical, technological and economic characteristics of water, which make it difficult to implement water markets, especially when compared with other economic instruments used for water allocation and management (Rosegrant et al., 1995; Bonnis et al., 2011).

The effectiveness of water markets is largely limited by the ability of potential sellers and buyers of water rights to first easily carry out a transaction and then to measure and transfer the respective quantities of water and to guarantee the quality required by each transaction (Hearne and Easter, 1997). Therefore, the flexibility of water markets depends on the availability of infrastructure for water storage and distribution. This means on the one hand that users may not be able to transfer quantities of water from one place to another or store the water they purchased until they need it due to the lack of suitable or sufficient infrastructure (Debaere et al., 2014). At the same time, unregulated purchase and sale of water rights through free, private agreements has the potential to cause negative impacts on users who do not participate in the transaction and negatively affect people, especially low-income farmers (Hearne and Easter, 1997).

In particular, the disadvantages of water markets can be summarized in the following points (Dinar et al., 1997; Holden and Thobani, 1996; Thobani, 1997; Lee and Jouravlev, 1998; Delorit and Block, 2018; Bonnis et al., 2011):

- In many countries there is a prevailing perception that water is a fundamental good for human survival and therefore its management should be under public control. In other words, it is considered that social benefits outweigh private economic benefits.
- There are practical difficulties associated with measuring water, defining rights and establishing an institutional framework for market formation as discussed in a previous section.
- The consumption of large quantities of water for urban and industrial use may lead to an increase in environmental pollution if appropriate measures are not taken.
- The transaction costs mentioned at length above are particularly high.
- The requirements for fixed capital investments are particularly high and the payback period for such capital is long, so there is a strong risk of monopolies developing.
- Government intervention can by no means be ruled out as there will always be issues directly linked to water in terms of flood control, disease and pollution that private initiative is unable or unwilling to resolve. This precludes the fully independent and seamless operation of any water market.
- There is always the risk of socio-economic inequality, i.e., people with low incomes being excluded from access to water. This is particularly true for small farmers who will either acquire limited water rights and will therefore be forced to switch to less water-intensive and therefore less profitable crops or will not acquire any water rights at all as these will end up with large companies and wealthy individuals.
- It cannot be ruled out that a monopoly or monopsony will be formed which will determine prices or even the emergence of speculation.
- Water markets are characterised by learning curves that are difficult to formulate on the part of users, since each user is confronted with a large number of other users who are potential buyers or sellers whose behaviour must gradually be decoded. This process is particularly time-consuming and difficult and is clearly more difficult than in the case where water is allocated by other methods or charged by simple billing.

International experience

This section attempts to summarise the development of water markets in the world. Water markets have been implemented primarily in regions outside Europe and in developed countries such as Australia and the United States of America. Among developing countries, only Chile has stood out in the development of water markets. Since water markets in each country operate under a specific social and institutional framework the experience gained from each country is different (Hadjigeorgalis, 2009; Mattheis et al., 2009). Fig. 7 summarises the international experience of establishing water markets in different regions of the world and then a more detailed account of this by continent is provided.

Europe

Water markets have not been widely implemented in Europe. This is due to the various obstacles that exist and make it difficult to implement them in this region, the main one being the difficulty in understanding the process. Indeed, there are countries such as France and Italy which have rejected the possibility of establishing water markets for decades. There are, of course, cases of informal water markets' establishment in Mediterranean regions with intensive agricultural activity (Rey et al., 2019; Mattheis et al., 2009).

The most prominent example of the implementation of water markets in Europe is Spain. In Spain in many areas facing water scarcity problems, there are informal water markets, which take the form of simple agreements between individuals to reallocate water without any central control. However, water markets were formally introduced in Spain in 1999 with the passing of Law 46/1999 and the first transactions took place a year later. This law included the legal framework under which water markets would operate in the future and provided for the establishment of formal water markets in the form of local markets and water banks (Palomo-Hierro et al., 2015). What this law essentially allowed was voluntary transactions of water quantities for an economic consideration among users at the river basin level and during periods of drought, provided that the quantities of water traded were allocated to corresponding or higher priority uses (Calatrava and Martinez-Granados, 2018). The Catalonia region in Spain is one of the areas where water markets have been established and farmers have the possibility to sell their water rights to other farmers or companies (Mattheis et al., 2009).

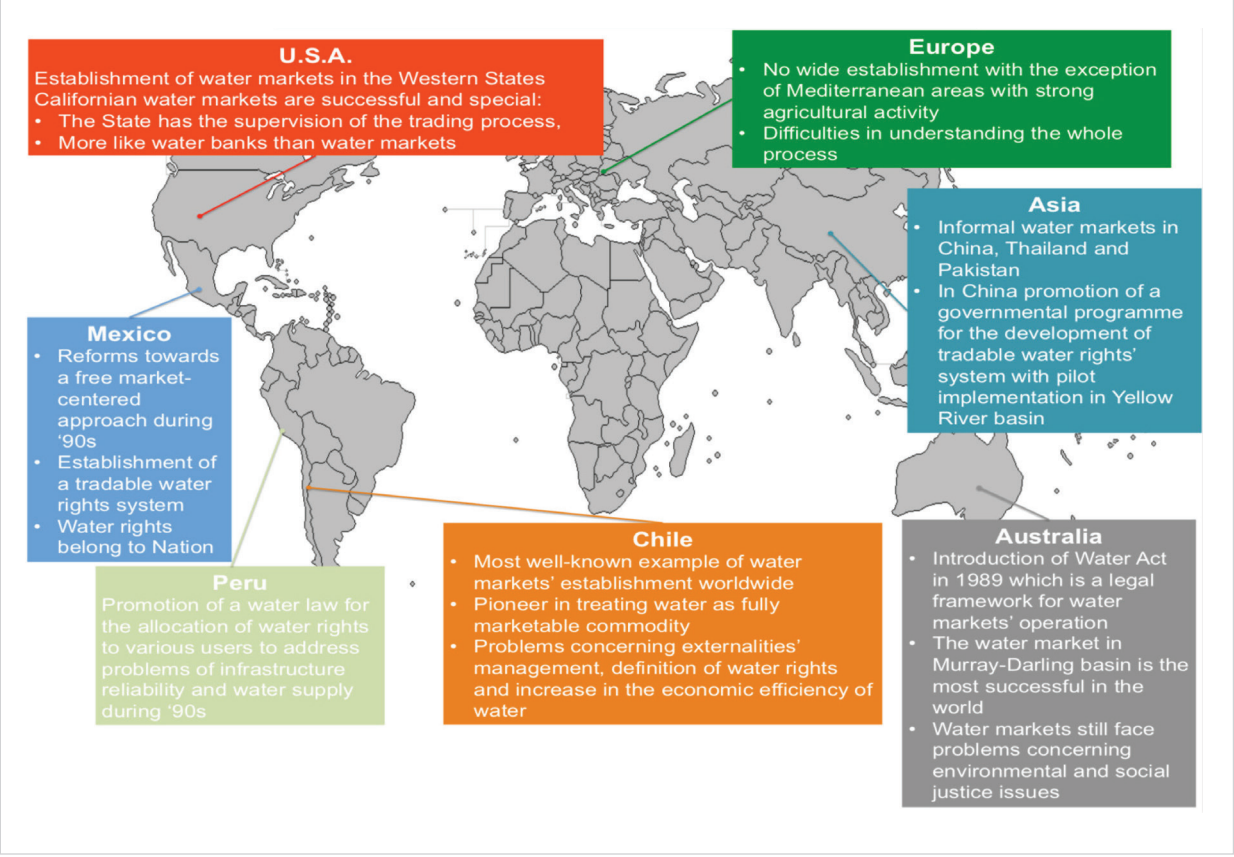
Americas

In the United States of America, water markets have been implemented mainly in Western States where high population growth has raised concerns about ensuring sufficient water for the population (Borghesi, 2014). Typical examples include the Rio Grande markets in the State of New Mexico, water markets in the States of Texas and California. In the former case where water rights are sold or leased on an annual or long-term basis, empirical evidence suggests that overall water use has eventually increased while raising social justice issues related to poorer users. In the second case, only those users who are able to make a profit can use water while in the third case, water rights transactions can only take place between a small number of agents and not between all users (Mattheis et al., 2009). The case of California is considered to be special and quite successful with the success being due to the fact that the oversight of the trading process is under the control of the State as well as the fact that the way it operates differentiates it from other water markets making it more similar to a water bank (Borghesi, 2014; Dinar et al., 1997).

The best known example of the implementation of water markets not only in the Americas but also around the world is that of Chile (Mattheis et al., 2009). The Chilean example has been used by researchers both to support the establishment of water markets and to oppose them. In Chile, water markets were part of a broader policy of free-market management of natural resources introduced by the military government of Augusto Pinochet, who took over the country in 1973, and based on the rulers' belief that the optimal and most efficient allocation of these resources should not be the responsibility of the State but of the market (Donoso, 2003). This policy intended on the one hand to promote private investment in the infrastructure used to manage water and on the other hand to reinforce the public belief that water is an object like all others and therefore can be wholly owned (Raffensperger and Milke, 2017). The latter pursuit is what differentiates Chile and makes

it a pioneer in approaching water as a fully tradable commodity (Bauer, 2005). Despite the widespread implementation of water markets in Chile for several decades, many problems still remain unresolved, the main ones being the management of externalities and the determination of water rights, while it seems that water markets do not confirm the initial expectation that accompanied their creation, which was to increase the economic efficiency of water (Mattheis et al., 2009).

Fig. 7. *Brief description of the international experience from water markets' establishment*



Source: own work

The idea of establishing water markets in Chile began in 1976 with the introduction of water rights alongside the re-privatisation of land that had been collectivised in 1966 (Rosegrant and Binswanger, 1994). However, it was the Chilean National Water Code which appeared in 1981 that established a system of tradable water rights completely independent of land tenure and use (Dinar et al., 1997). The 1981 Chilean National Water Code was seen by some as a successful neoliberal reform, highlighting the benefits of the contribution of free market forces to more efficient water management, and by others as an ideological and social aberration due to the complete liberalization of water trading (Bauer, 1997; Bauer, 2005).

Chile's approach to water has been an inspiration for many Central and South American countries such as Mexico and Peru. In Mexico in particular, as the country's economy was driven towards a free market-centred approach it was increasingly understood that the establishment of a system of tradable water rights offered flexibility in the face of changes in water demand. For this reason, reforms were promoted

during the 1990s. The main difference with the legal framework established in Chile is that in Mexico water rights are the property of the Nation and not of private individuals, who of course grant their use for a period of five to fifty years to them (Holden and Thobani, 1996). Water rights transactions in Mexico provided an excellent source of income and debt repayment for poor farmers who had accumulated exorbitant debts due to unprofitable crops (Thobani, 1997). In the case of Peru, during the 1990s there were severe problems with the reliability of the water infrastructure and consequently the supply of sufficient quantities of water for urban and rural use. In order to address these problems, the government of the country promoted a law related to water that provided for the allocation of water rights to different users without charge which could then be traded under a specific set of regulations and rules (Holden and Thobani, 1996).

Asia

In Asia, informal water markets have been established to allocate groundwater in China, Thailand, India and Pakistan, mainly in areas with water scarcity problems. These markets are seen as flexible and are under community control (Hadjigeorgalis, 2009). In terms of formal water markets, in China, the government since the beginning of the millennium has changed the way water is managed by promoting a programme to develop a tradable water rights system, i.e., by establishing water markets. This programme has already been piloted in areas of North China such as the Yellow River Basin (Wang, 2012). In general, however, it is generally considered that this program is more a project of sensationalism than substance (Wang et al., 2019).

Australia

Australia, which is the driest continent on Earth, is another case of the implementation of water markets. When water markets were first established in Australia, an adequate and appropriate legal framework governing their operation was not developed, resulting in social, environmental and economic impacts. Such a framework was formalised in 1989 with the introduction of the Water Act, which provided for regulations to govern water rights transactions (Mattheis et al., 2009). In 2014, new rules were introduced to regulate the conflicts that often arise from the operation of markets (Raffensperger and Milke, 2017). The most prominent example of a successful water market not only in Australia but around the world is that of the Murray-Darling catchment, a region with large variations in rainfall and at the same time high water demands both for agricultural production as about one-third of Australia's food supplies are produced there and for domestic consumption as more than two million people live in the area (Raffensperger and Milke, 2017; Loch et al., 2013). This success is due in large part to the way water markets in Australia have been designed – separating water rights from land ownership and offering users different types of rights such as long-term access to a specific amount of water and simple annual allocations – but also to particular characteristics of this region such as the large number of farmers who consume 80% of the total amount of water consumed in the Murray-Darling region and the public funding of the project (Breviglieri et al., 2018). Despite their success, of course, water markets in Australia still face problems, the main ones being those related to environmental issues and those related to social justice issues, as in this case there is also the phenomenon of the predominance of large farmers over smaller farmers at the crop level (Borghesi, 2014).

Conclusions

This paper is a systematic literature review that aims to present an overview of water markets and the international experience gained from their establishment and operation in various countries. To achieve this purpose, 91 relevant studies found after a search of scientific databases were thoroughly studied by setting specific criteria.

The study of the selected literature sources led to the collection of information on the precise definition of water markets, the background behind them, the main categories into which they are divided, their main features, the conditions that have to be met for them to operate effectively, the advantages and disadvantages they present as methods of allocating water to different users and as an economic instrument for demand management, and the establishment of water markets in various countries. This information was organised

and presented in an appropriate manner.

The general conclusion drawn from this paper is that water markets are a worthwhile alternative for allocating water to competing users and thus for the efficient management of this natural resource and therefore have been implemented in several countries. At the same time, in addition to this general conclusion, the following individual conclusions also emerge:

- first, the most important advantage put forward by the proponents of water markets is that they increase the economic efficiency of water by encouraging users who have no or limited economic benefit from water use to sell the amount of water allocated to them to users who are able to derive large economic benefits from it;
- secondly, the main disadvantage raised by those who do not support water markets relates to issues of social justice, as it is considered that the way a water market operates essentially excludes low-income users from consuming this fundamental resource;
- thirdly, the establishment and operation of water markets has been largely linked to neoliberal economic policies implemented mainly in Latin American countries since the 1970s. This fact, combined with the fact that their focus is on viewing water as an economic good, the high transaction costs and the difficulty of establishing a perfectly fair legal framework governing their operation, makes water markets cautiously considered by many researchers.

Taking into account all of the above, it is fully understood that despite any disadvantages associated with the establishment and operation of water markets, and given that the need for efficient methods of water resources management still exists, exploring the possibilities of modifying their operational context to make them not only a cost-effective but also a socially equitable solution for water management and distribution is a challenge for the scientific community.

In general, this study could be used as the theoretical basis for the construction of operational research models that intend to make the operation of water markets better and more efficient and it could also be used as a useful source of information for scholars that deal with water markets.

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Appendix

Table 5. *Main features of formal and informal water markets (Source: own work)*

No	Author(s)	Year	Continent of origin	Document type	Type of study
1	Aghaie et al.	2020	Asia	Journal paper	Quantitative
2	Andersen	2001	Europe	Report	Qualitative
3	Armitage et al.	1999	Africa	Journal paper	Quantitative
4	Bauer	1997	Americas	Journal paper	Qualitative
5	Bauer	2005	Americas	Journal paper	Qualitative
6	Bekchanov et al.	2013	Europe	Report	Quantitative
7	Bekchanov et al.	2015	More than one	Journal paper	Quantitative
8	Bjornlund	2004	Australia	Journal paper	Qualitative
9	Bjornlund and McKay	2002	Australia	Journal paper	Qualitative
10	Bonnis et al.	2011	More than one	Conference paper	Qualitative
11	Buzolic et al.	2021	Americas	Journal paper	Quantitative
12	Borghesi	2014	Europe	Journal paper	Qualitative
13	Breviglieri et al.	2018	Americas	Journal paper	Quantitative
14	Calatrava and Martinez-Granados	2018	Europe	Journal paper	Quantitative
15	Campanhao et al.	2021	Americas	Journal paper	Qualitative
16	Chiueh and Huang	2015	Asia	Journal paper	Quantitative
17	Chong and Sunding	2006	Americas	Journal paper	Qualitative
18	Colby	1988	Americas	Journal paper	Qualitative
19	Crase et al.	2000	Australia	Journal paper	Qualitative
20	Debaere	2014	Americas	Journal paper	Quantitative
21	Debaere and Li	2017	Americas	Conference paper	Quantitative
22	Debaere et al.	2014	Americas	Journal paper	Quantitative
23	Delorit and Block	2018	Americas	Journal paper	Quantitative
24	Deng et al.	2018	Asia	Journal paper	Quantitative
25	Dinar et al.	1997	Americas	Report	Qualitative
26	Donohew	2009	Americas	Journal paper	Qualitative
27	Donoso	2003	Americas	Report	Quantitative
28	Dou et al.	2019	Asia	Journal paper	Quantitative
29	Draper	2005	Americas	Journal paper	Qualitative
30	Easter and Huang	2014	Americas	Special issue	Qualitative and Quantitative
31	Easter et al.	1999	Americas	Report	Qualitative
32	Ellerman	2005	Americas	Journal paper	Qualitative

No	Author(s)	Year	Continent of origin	Document type	Type of study
33	Endo et al.	2018	More than one	Journal paper	Qualitative
34	Erfani et al.	2015	Europe	Journal paper	Quantitative
35	Hadjigeorgalis	2009	Americas	Journal paper	Qualitative
36	He et al.	2021	Asia	Journal paper	Quantitative
37	Hearne and Easter	1997	More than one	Journal paper	Quantitative
38	Hearne and Trava	1997	Europe	Report	Qualitative
39	Hernandez-Mora and Moral	2015	Europe	Journal paper	Quantitative
40	Hill and Tollefson	1996	Americas	Book chapter	Qualitative
41	Hodgson	2006	Europe	Report	Qualitative
42	Holden and Thobani	1996	Americas	Report	Qualitative
43	Howe and Goemans	2003	Americas	Journal paper	Quantitative
44	Howe et al.	1986	Americas	Journal paper	Quantitative
45	Jakeman et al.	2016	More than one	Special issue	Qualitative and Quantitative
46	Koopman et al.	2017	Europe	Journal paper	Quantitative
47	Koundouri and Papandreou	2014	More than one	Special issue	Qualitative and Quantitative
48	Kraemer et al.	2004	Americas	Report	Qualitative
49	Latinopoulos	2016	Europe	Journal paper	Quantitative
50	Latinopoulos and Sartzetakis	2014	Europe	Journal paper	Quantitative
51	Lee and Jouravlev	1998	Americas	Report	Qualitative
52	Lewis and Zheng	2018	More than one	Journal paper	Qualitative
53	Li et al.	2019	Asia	Journal paper	Quantitative
54	Liu et al.	2016	Asia	Conference paper	Quantitative
55	Loch et al.	2013	Australia	Report	Qualitative
56	Matchaya et al.	2019	Africa	Journal paper	Qualitative
57	Mattheiss et al.	2009	Europe	Report	Qualitative
58	Meran et al.	2021	Europe	Book	Qualitative and Quantitative
59	McKinney and Savitsky	2006	Americas	Report	Qualitative and Quantitative
60	Montilla-Lopez et al.	2016	Europe	Journal paper	Qualitative
61	Palomo-Hierro et al.	2015	Europe	Journal paper	Qualitative
62	Pharino	2007	Americas	Book	Qualitative
63	Prabondanie	2010	Australia	PhD thesis	Qualitative and Quantitative
64	Raffespenger and Milke	2017	More than one	Special issue	Qualitative and Quantitative
65	Rey et al.	2019	Europe	Journal paper	Qualitative

No	Author(s)	Year	Continent of origin	Document type	Type of study
66	Richter	2016	Americas	Report	Qualitative
67	Rios and Quiroz	1995	Americas	Journal paper	Qualitative
68	Rodriguez-Flores et al.	2019	Americas	Journal paper	Quantitative
69	Rosegrant and Binswanger	1994	Americas	Journal paper	Qualitative
70	Rosegrant et al.	1995	More than one	Journal paper	Qualitative
71	Rosegrant et al.	2000	Americas	Journal paper	Quantitative
72	Schwabe et al.	2020	More than one	Journal paper	Qualitative
73	Seidl et al.	2020	Australia	Journal paper	Quantitative
74	Simpson and Ringskog	1997	Americas	Report	Qualitative
75	The Allen Consulting Group	2006	Australia	Report	Qualitative
76	Thobani	1997	Americas	Report	Qualitative
77	Tietenberg	2006	Americas	Journal paper	Qualitative
78	Venkatachalam	2015	Asia	Journal paper	Quantitative
79	Viaggi et al.	2014	Europe	Special issue	Qualitative and Quantitative
80	Villanueva and Glenk	2021	Europe	Journal paper	Quantitative
81	Walter et al.	2010	Europe	Report	Quantitative
82	Wang	2012	Asia	Journal paper	Quantitative
83	Wang et al.	2018	Asia	Journal paper	Quantitative
84	Wang et al.	2019	Asia	Journal paper	Quantitative
85	Wang et al.	2020	Asia	Journal paper	Quantitative
86	Wheeler et al.	2020	Australia	Report	Qualitative
87	Xu et al.	2018	More than one	Journal paper	Quantitative
88	Zeng et al.	2014	More than one	Journal paper	Quantitative
89	Zhang et al.	2013	Asia	Journal paper	Quantitative
90	Zhang et al.	2020	Asia	Journal paper	Quantitative
91	Zhu et al.	2015	More than one	Journal paper	Quantitative