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Socioeconomic and environmental impacts of water markets: a literature review

Impactos socioeconômicos e ambientais dos mercados de água: uma revisão da literatura

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ABSTRACT: The water market is an economic instrument for the water allocation among different users, particularly in locations and periods of water scarcity. Although several authors defend the instrument as beneficial for the conservation and efficient use of water resources, other effects, such as issues of equity, sustainability and environmental impacts need to be assessed. This article focuses on identifying the economic, social and environmental impacts of water markets through a review of the literature. The searches were conducted in Scopus and Web of Science bases, where 235 studies were screened. 48 of these studies were included in the review, and most of them report only economic impacts, such as effects on landowners' income, agricultural production and efficiency of water use. On the other hand, social and environmental impacts were poorly evaluated by the studies. Social impacts mainly include issues of distribution of market benefits and access to water and rights. Of the environmental impacts, the effects on the environmental flow of rivers and reservoirs, as well as on the levels in the aquifers, stand out. It is concluded that the literature is still incipient in documenting the impacts of water markets in terms of diversity of effects, and further studies are needed to assess environmental impacts and equity and justice in access to water.

Keywords: economic mechanisms; water resources management; water allocation; water use rights.

RESUMO: O mercado de água é um instrumento econômico para a alocação da água entre diversos usuários, especialmente em locais e períodos de escassez hídrica. Embora diversos autores defendam o instrumento como benéfico para a conservação e uso eficiente dos recursos hídricos, outros efeitos, como questões de equidade e sustentabilidade ambiental precisam ser avaliados. Este trabalho tem como objetivo identificar os impactos econômicos, sociais e ambientais dos mercados de água por meio de uma revisão da literatura. As buscas foram conduzidas nas bases Scopus e Web of Science, em que 235 estudos foram capturados. 48 desses estudos foram incluídos na revisão, cuja maioria analisava apenas impactos econômicos, tais como efeitos na renda dos produtores rurais, na produção agrícola e na eficiência no uso da água. Por outro lado, impactos sociais e ambientais foram pouco avaliados pelos estudos. Os impactos sociais compreendem principalmente questões de distribuição dos benefícios do mercado e acesso à água e aos direitos. Dos impactos ambientais, destacam-se os efeitos dos mercados na vazão ambiental de rios e reservatórios, bem como nos níveis de aquíferos. Conclui-se que a literatura ainda é incipiente na documentação dos impactos dos mercados de água em termos de diversidade de efeitos, sendo necessários mais estudos que avaliem os impactos ambientais e de equidade e justiça no acesso à água.

Palavras-chave: instrumentos econômicos; gestão dos recursos hídricos; alocação da água; direito de uso da água.

1. Introduction

As national command and control policies and regional and local water markets, different mechanisms are employed for the allocation of water during drought periods (Koopman *et al.*, 2017). Wheeler *et al.* (2017, p. 808) define water markets as 'the voluntary buying and selling of water in some quantifiable form; either in the present or future.' Three key elements, namely water rights, water trading mechanisms and physical infrastructure for water transfer, characterize them (Bakker, 2014). Such markets can be categorized as (i) short-term or temporary markets, (ii) medium-term leasing of water allocations, and (iii) permanent transfers of water entitlements (Wheeler *et al.*, 2017). They have become a popular water management strategy due to their alleged benefits, e.g., the efficiency achieved by promoting reallocation according to users' demands (Wheeler *et al.*, 2014b; Grafton *et al.*, 2016). The inefficient use of water and the introduction of neoliberal policies have boosted the implementation of water markets as a management strategy to improve the performance of the water sector (Meinzen-Dick, 2007).

Water markets can be formal or informal; the former are legally implemented and regulated, while the latter are not (Thobani, 1997). Informal water markets have emerged mainly in places where the government cannot manage water demand during scarcity (Mukherji, 2007b). Water trade can occur among several local water users, although most transactions are between urban users (buyers) and farmers (sellers) (Summitt, 2011). When farmers stop cultivating the land, a water surplus is created, which can be sold to more efficient users (Summitt 2011).

Water markets encourage the conservation and efficient use of water (Thobani, 1997; Summitt, 2011) through the pricing of water (Summitt, 2011), thus providing benefits to buyers and sellers during water shortages (Grafton *et al.*, 2011), and positive socio-economic impacts (Thobani, 1997). Potential socio-economic impacts include increased employment and income, which can alleviate rural poverty (Thobani, 1997).

In places like the Western United States, Chile (Grafton *et al.*, 2011), Australia (Grafton *et al.*, 2016) and India (Manjunatha *et al.*, 2016), water markets have already been established. In other countries, the legal framework of water rights does not allow formal water trade among users. In Brazil, for example, there are no formal water trading schemes, since the 1988 Federal Constitution defines water as a public common good. This possession cannot be transferred; therefore, to establish a market considering water as owned by private holders would be unconstitutional (Lanna & Braga, 2006).

Although several authors argue that water markets are a positive strategy, other evidence indicates adverse impacts. According to Skurray *et al.* (2012), the impacts of water markets can range from simple and easily compensated to complex and uncertain effects, which vary spatially and temporally. They can cause agricultural job losses (Summitt, 2011), undermine livelihoods due to political pressure to transfer water (Bakker, 2014), and reduce environmental flows (Kahil *et al.*, 2016).

Several factors modulate the performance of water markets and their impacts on socio-ecological systems, e.g., transaction costs (Skurray *et al.*, 2012; Regnacq *et al.*, 2016), asymmetric information and access barriers (Romano & Leporati, 2002), the existence of secure and tradeable water rights, third party effects (Skurray *et al.*, 2012), presence of regulatory agencies (Grafton *et al.*, 2011; Summitt, 2011; Skurray *et al.*, 2012; Skurray *et al.*, 2013; Manjunatha *et al.*, 2016; Wheeler *et al.*, 2017), market design and operation rules (Grafton *et al.*, 2016), and perceptions of fairness and equity (Syme *et al.*, 1999).

Despite claims of greater efficiency in water use, equity issues (Grafton *et al.*, 2011; Endo *et al.*, 2018) and sustainability of water markets should be assessed (Grafton *et al.*, 2011). A robust water market should address future, third party, and non-monetizable impacts to maintain or improve overall welfare (Skurray *et al.*, 2012). Such impacts should also be monitored and evaluated to minimize adverse effects (Poddar *et al.*, 2014). In 2012, Skurray *et al.* (2012) stated that studies aimed at explicitly analysing the range of potential impacts had been rare. This gap persists today and, due to the increasing interest in water trading schemes as a management measure, this study aims to identify the impacts of water markets on the socio-economic and environmental dimensions reported in the scientific literature.

2. Material and methods

We performed a review of the literature to answer the following question: 'What are the impacts of water markets on water resources management regarding to the environmental, social and economic dimensions?'. The research was based on the systematic review protocol (Higgins & Green, 2011) and was conducted in April 2018 in Scopus and Web of Science, which are complementary databases covering the leading journals of natural sciences and engineering (Mongeon & Paul-Hus, 2016). The following Boolean expression with keywords in English was used: 'water markets' AND 'impact.'[1]. The search was performed in the 'article title, abstract, keywords' and 'topic'[2] fields of Scopus and Web of Science, respectively. We

[1] '' = used for grouping words and searching for the expression in parentheses; AND = Boolean operator that means addition.

[2] topic = title, abstract, author keywords, and Keywords Plus®.

considered only documents published after 1998 to limit the search to the last 20 years.

We use these keywords and search strategy to identify a good proportion of relevant studies, avoiding the retrieval of many non-relevant studies, i.e., increasing its scope and maintaining its accuracy (Higgins & Green, 2011). We do not consider specific keywords such as 'efficiency' to limit the author bias, i.e., directing the review to topics previously known by the authors, e.g., the economic efficiency of water markets (Bilotta *et al.*, 2014). Therefore, other researchers can perform a review using different databases and keywords and find complementary results.

The records were transferred to the Zotero reference management software, and the repeated results were merged. Each study was read under different filters, namely article title, abstract and keywords, introduction and conclusion, and the full text. Eligibility criteria (Table 1) were applied for the selection and exclusion of studies.

The impacts of water markets were extracted from studies included and categorized into three dimensions: 1) Economic impacts, which address the effects on water use efficiency, user income, agricultural production; 2) Social impacts, which focus on equity and fairness issues (Syme *et al.*, 1999), such as the distribution of benefits, access to water rights and user perceptions; and 3) Environmental impacts, which consider the effects on environmental flows and water levels in the aquifers.

3. Results and discussion

We recovered 214 Scopus records and 77 Web of Science records. After merging repeated results, we read 235 studies. 101 records were excluded by title, keywords and abstract; 49 were excluded by introduction and conclusion; 37 were excluded by the full reading of the text; and 48 studies were included in the review. One duplicate study led to the exclusion of one record. Table 2 shows the characteristics of the water markets analyzed for each study included, i.e., real or hypothetical market, location of the case studies and type of impacts identified.

TABLE 1 – Eligibility criteria for the selection of studies in the literature review.

Criterion	Inclusion	Exclusion
Publication date	Studies published after 1998	Studies published before 1998
Language	Studies written in English	Studies written in other languages
Document type	Journal articles and book chapters	Conference papers
Full-text availability	Full text available	Full text not available
Focus of the study	Water markets, i.e., water transactions between buyers and sellers	Other objects of study
Contribution of the study	Studies that analyze, discuss, and identify impacts (economic, social, or environmental) of water markets	Studies that do not analyze, discuss, or identify impacts (economic, social, or environmental) of water markets. Review articles that only compile impacts and do not provide a new conclusion based on the results

TABLE 2 – Type of water market, location of the study area, and impacts identified by the studies included in the literature review.

Author (year)	Type[a]	Study area	Country	Impacts[b]		
				Eco.	Env.	Soc.
Arriaza *et al.* (2002)	H	El Bajo Guadalquivir	Spain	+		
Ballestero *et al.* (2002)	H	Lorca countryside	Spain	+		
Bjornlund (2003)	R	Goulburn-Murray, Victoria	Australia	+		-
Bjornlund (2007)	R	Goulburn-Murray, Victoria	Australia	-		+
Boehlert & Jaeger (2010)	H	Upper Klamath Basin, Oregon, and California	United States	+		
Budds (2004)	R	La Ligua and Petorca valley, Norte Chico	Chile			-
Connor *et al.* (2013)	H	Murrumbidgee catchment, Murray-Darling Basin, New South Wales	Australia	0	+	
Edwards *et al.* (2008)	R	Murray-Darling basin	Australia			-
Giannoccaro *et al.* (2011)	R	Fortore River basin	Italy	+/-		-
Gillig *et al.* (2004)	H	Edwards Aquifer region, Texas	United States	-	-	
Gómez *et al.* (2004)	H	Balearic Islands, Iberian Peninsula	Spain	+/-		
Grafton *et al.* (2016)	R	Murray-Darling basin	Australia	+	+	
Hadjigeorgalis (2008)	R	Limarí River Basin	Chile	+		
Hasselman & Stoker (2017)	R	Murray-Darling basin	Australia			-
Howe & Goemans (2003)	R	South Platte and Arkansas basins, Colorado	United States	+/-		
Howitt *et al.* (2012)	H	San Joaquin Valley, California	United States	+		
Kahil *et al.* (2015a)	H	Jucar River basin	Spain	+	-	
Kahil *et al.* (2015b)	H	Jucar River basin	Spain	+	-	
Knapp *et al.* (2003)	H	Kern county, California	United States	+/-	+	
Koopman *et al.* (2017)	H	River basins of Rhine and Meuse rivers	Netherlands	+/-		
Libecap (2005)	R	Owens Valley, California	United States			-
Llop & Ponce-Alifonso (2016)	H	Catalonia	Spain	+	+	
Louw & Van Schalkwyk (2000)	H	Upper-Berg River, Western Cape	South Africa	+		
Manjunatha *et al.* (2016)	R	Eastern Dry Zone, Karnataka State	India	+		
Mukherji (2007a)	R	Mohanpur village, Hugli district	India			-
Mukherji (2007b)	R	West Bengal	India	+		+
Murali *et al.* (2015)	H	-	-	+/-	+/-	
Pujol *et al.* (2006a)	H	Six main irrigation communities of the Muga and Ter rivers, Catalonia	Spain	+		
Pujol *et al.* (2006b)	H	Low Ter, Catalonia; and Reclamation and Irrigation Board area of Capitanata, Foggia	Spain and Italy	+		

Qureshi & Whitten (2014)	R	Southern Murray-Darling basin	Australia	+		
Qureshi *et al.* (2013a)	R	Southern Murray-Darling basin	Australia	+		
Qureshi *et al.* (2013b)	H	Murray-Darling basin	Australia	+		
Reddy *et al.* (2015)	H	Brazos River basin	United States	+		
Rey *et al.* (2016)	H	Tagus-Segura Transfer	Spain	+	+	
Romano & Leporati (2002)	R	Limarí Province	Chile			-
Solís & Zhu (2015)	H	Extremadura	Spain	+		
Straton *et al.* (2009)	H	Katherine-Daly River system	Australia	-/0		
Strosser (1998)	H	Secondary canals Fordwah and Azim, Chishtian Sub-division, South Punjab	Pakistan	0		
Tanaka & Lund (2003)	H	Sacramento Valley, California	United States	+		
Thiam *et al.* (2015)	H	Olifants River basin	South Africa	+		+
Thompson *et al.* (2009)	H	Republican basin, Nebraska	United States	+		
Tisdell (2001)	R	Border Rivers region, Queensland	Australia		-	
Ward *et al.* (2006)	H	Rio Grande basin	United States and Mexico	+		
Wheeler *et al.* (2014a)	R	Murray-Darling basin	Australia	0		
Whited (2010)	R	Uvalde county, Texas	United States	-		
Zaman *et al.* (2009)	R	Goulburn-Broken catchment	Australia	+/-		
Zekri & Easter (2005)	H	Bouhertma, Governorate of Jendouba	Tunisia	+/-/0		
Zhang *et al.* (2016)	R	Hebei and Henan provinces	China	+		

Legend: [a] Real (R) or hypothetical (H) water market. Hypothetical markets include those not implemented at the time of the study. [b] The impacts are classified as positive (+), negative (-), or limited (0). Limited impacts (0) indicate that the author classified them as not significant. Eco. = economic; Env. = environmental; Soc. = social.

Most studies (27) assessed the impacts of hypothetical water markets (i.e., not implemented), while 21 studies identified the impacts of real ones. 118 authors are associated with the 48 studies, and three authors have a dual affiliation. Most of the authors are based in the United States, followed by Australia and Spain (Figure 1).

We identified 48 study areas from the 48 studies, and one site covered two countries. The study areas are concentrated in Australia, the United States, and Spain (Figure 2).

The main research method used by the studies to estimate the impact of real or hypothetical water markets was the economic models (67%). Other methods employed include interviews, theoretical reviews, analyses of secondary data, and regression models.

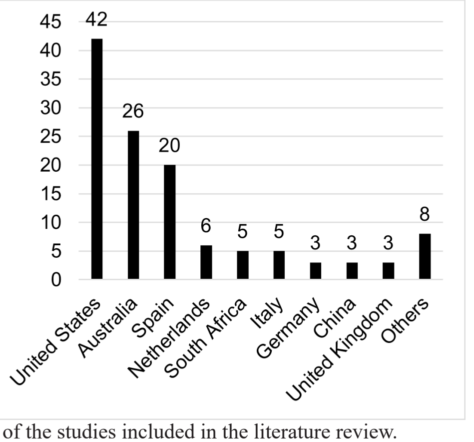

FIGURE 1 – Authors' country of affiliation of the studies included in the literature review.

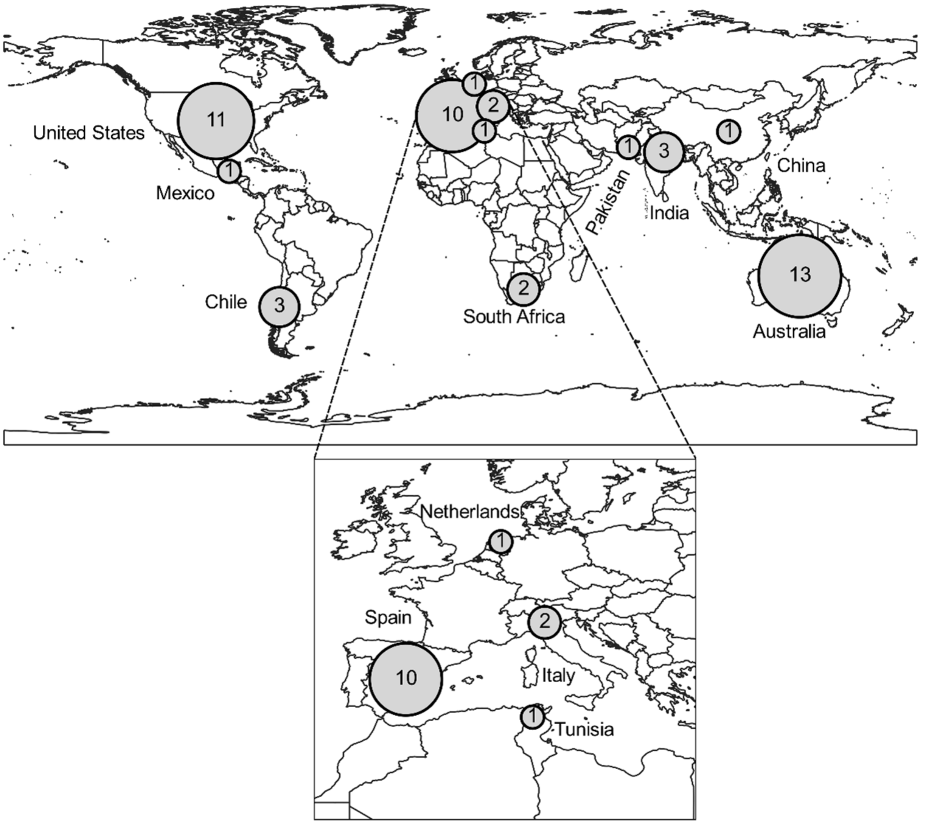

FIGURE 2 – Spatial location of study areas of the articles included in the literature review.

Most studies have analyzed or identified only the economic impacts of water markets (56%), while the other dimensions have been neglected (Figure 3). Impacts on all three dimensions (i.e., economic, social, and environmental) were not assessed or identified by the studies. The following sections describe and discuss the impacts by dimension.

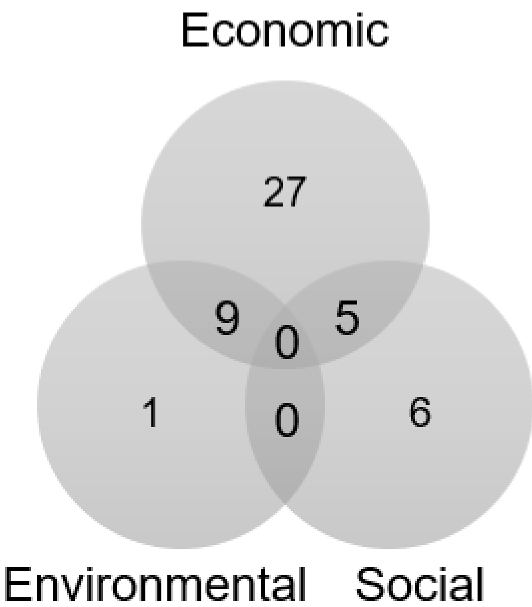

FIGURE 3 – Number of studies that identified impacts on the economic, social, and environmental dimensions.

3.1. Economic impacts

Several authors have stated that water markets are a strategy to improve water use efficiency (Tanaka & Lund, 2003; Pujol *et al.*, 2006b; Thompson *et al.*, 2009; Solís & Zhu, 2015; Thiam *et al.*, 2015; Manjunatha *et al.*, 2016; Zhang *et al.*, 2016). Trading provides flexibility to farmers as they can adjust the amount of water used according to climatic conditions (Zhang *et al.*, 2016), and encourage water reallocation by adapting users' water consumption levels (Solís & Zhu, 2015). Water pricing associated with trade also contributes to the efficient use of water resources (Thiam *et al.*, 2015). By reducing water losses due to evaporation or transpiration, trade can strongly impact water use efficiency in irrigated areas (Thompson *et al.*, 2009; Kahil *et al.*, 2015b). Irrigated farms that participate in water trading as buyers or sellers are more efficient than farms that do not participate (Manjunatha *et al.*, 2016). However, the efficiency gains in relation to actual transaction costs may be modest (Pujol *et al.*, 2006b). This highlights the importance of regulatory agencies to keep them low (Pujol *et al.*, 2006b).

Water trading can impact water availability and consumption, thus affecting water users. Theoretically, a region that imports water through a water market would be positively affected by higher levels of aquifer; hence, lower water prices (Murali *et al.*, 2015). On the other hand, a region that exports water through a water market would be negatively affected due to limited water availability and consequently higher water prices (Murali *et al.*, 2015). The implementation of water trade and the increase in the number of extraction licenses can increase the volume of water abstracted (Straton *et al.*, 2009). According to studies in Northern Australia, this effect can imply pumping restrictions to farmers, thus affecting their profit, which is only partially offset by the trade (Straton *et al.*, 2009). Nevertheless, more farmers will seek other sources of income (Straton *et al.*, 2009). In the long term, water availability in the irrigation system can decrease due to trading, and third parties can be affected by the increasing or limiting water availability in certain regions (Zaman *et al.*, 2009). On the other hand, Llop &Ponce-Alifonso (2016) verified that water markets could reduce water consumption if combined with a principle of cost recovery. Zhang *et al.* (2016) observed that farmers who buy water from groundwater markets consume less water than those who obtain water from their own or collective tubewells, and both obtain similar crop yields.

Trading allows farmers to decide whether to use or sell water (Qureshi & Whitten, 2014) and encourage reallocation to more efficient users (Louw & Van Schalkwyk, 2000). Consequently, the economic costs and losses associated with climate variability can be alleviated (Louw & Van Schalkwyk, 2000; Bjornlund, 2003; Boehlert & Jaeger, 2010; Qureshi *et al.*, 2013a; Qureshi & Whitten, 2014; Reddy *et al.*, 2015; Grafton *et al.*, 2016), and access to water can be assured when transfers are restricted during drought periods (Rey *et al.*, 2016).

When combined with on-farm technologies, water trade can alleviate the economic losses of agricultural production during periods of reduced rainfall and increased salinity and evapotranspiration (Qureshi *et al.*, 2013a). However, this is likely to occur in scenarios with small reductions in water availability (Qureshi *et al.*, 2013a). In severe drought scenarios, water markets can reduce net economic losses if combined with other environmental flow management policies (Boehlert & Jaeger, 2010). On the other hand, in industrialized watersheds, limited impacts on water shortage are expected, as few users would sell water to urban and industrial users during droughts (Reddy *et al.*, 2015). Water markets can mitigate the impacts caused by drought by reducing gross agricultural losses by 14% (Qureshi *et al.*, 2013b) and economic losses by 20% up to 33% (Ward *et al.*, 2006) and improving farmers' income by about 26% (Kahil *et al.*, 2015a).

Studies have cited contrasting impacts of water trading on farm income (Strosser, 1998; Zekri & Easter, 2005; Pujol *et al.*, 2006a; Mukherji, 2007b; Straton *et al.*, 2009; Thompson *et al.*, 2009; Zaman *et al.*, 2009; Wheeler *et al.*, 2014a; Grafton *et al.*, 2016; Llop & Ponce-Alifonso, 2016) and regional net benefits (Knapp *et al.*, 2003). Farmers can improve their income through water sales (Mukherji, 2007b; Zaman *et al.*, 2009; Llop & Ponce-Alifonso, 2016). However, such economic gain might be moderate in scenarios of low water availability (Pujol *et al.*, 2006a) and depend on both allocation size and land variables (Thompson *et al.*, 2009). Zekri & Easter (2005) verified that the Tunisian farmers' income increased when trade occurred between them and urban users, although the latter must pay more than the opportunity cost of water. However, farmers are likely to store water instead of selling it due to the former's higher profitability (Zekri & Easter, 2005). When farmers are selling water, the area of irrigated land is reduced, which can affect their income (Gillig *et al.*, 2004; Gómez *et al.*, 2004). However, they can compensate these income losses by shifting production to less profitable crops (Arriaza *et al.*, 2002; Ballestero *et al.*, 2002; Gómez *et al.*, 2004).

Some studies did not find a strong correlation between farmers' participation in the water market and economic gains (Straton *et al.*, 2009; Wheeler *et al.*, 2014a). According to Wheeler *et al.* (2014a), this result can be explained by the characteristics of the studied period, i.e., high prices and low water allocations. Strosser (1998) observed a low impact of water markets on farms' gross income.

The lack of adequate infrastructure to store water, the homogeneity of farms' productivity and the abundance of water may have influenced the results (Strosser, 1998). The introduction of water markets can increase individual net benefits and decrease regional net benefits, as farmers aim to maximize their profit without considering the costs associated with extracting and transporting water to other regions (Knapp *et al.*, 2003).

The reallocation of water can cause mixed impacts on the local economy and agricultural production. Due to improvements in the efficiency of water use, farms may specialize in high value-added crops, thus obtaining higher incomes (Pujol *et al.*, 2006b). However, as addressed by Pujol *et al.* (2006b), transaction costs can dramatically affect these results. By analyzing water reallocation from inefficient, unproductive, and low value users to efficient, productive and high value users, Bjornlund (2007) showed that the more water sold, the lower the productivity of the sellers' farms. Giannoccaro *et al.* (2011), investigating the effects of two water trading scenarios (an intra-sector market and a regional market) on the Fortore river basin in Italy, also identified impacts on agricultural production. In the intra-sector market, as less intensive farms sold water to intensive farms, both marginal productivity and profitability increased. On the other hand, as intensive farms bought water, their marginal productivity was reduced, and their profitability increased. In the regional scenario (i.e., market with a water use rights auction system), intensive farms increase their profitability, while less intensive farms face losses due to the higher marginal productivity of intensive farms (Giannoccaro *et al.*, 2011).

Water sales can provide funds for farmers to invest in rural properties (e.g., through the implementation of more efficient cultivation and irrigation systems and conversion to high value-added crops) or for debt settlement (Hadjigeorgalis, 2008; Kahil *et al.*, 2015a). Without water trading, low-income farmers (i.e., water sellers) would take the risk of cultivating during drought periods or leaving the land fallow (Hadjigeorgalis, 2008). When entering the water market, sellers could leave a higher portion of their lands fallow to make water available for reallocation (Hadjigeorgalis, 2008).

A significant change in total fallow irrigated areas due to the implementation of water markets was also observed in San Joaquim Valley in California, USA. Approximately 87,000 ha of irrigated areas were left fallow during drought periods, and this value decreased by 16% with the implementation of a water market (Howitt *et al.*, 2012). However, in less productive regions, farmers choose to increase the amount of fallow land and export the surplus water to more profitable farms (Howitt *et al.*, 2012), or where the production losses caused by drought can be compensated (Kahil *et al.*, 2015a).

Water trade between farmers and urban users can negatively impact the input markets and labor demands of the exporting region (Howe & Goemans, 2003; Zekri & Easter, 2005). Demand for labor and input costs decrease due to reduced agricultural production in the exporting region (Zekri & Easter, 2005). Whited (2010) simulated a scenario where all irrigation water used in a county is transferred to another county and verified several impacts on the local economy. As a result of the water transfer, low input crops were adopted, which significantly affected the output, labor income and employment in the exporting county (Whited 2010). Howe & Goemans (2003) showed that water sales can negatively affect the economic activities associated with the agricultural production (i.e., suppliers of agricultural input can lose business and financial institutions can lose demand for loans), and harm local communities (i.e., reducing employment opportunities and provision of public services). Nevertheless, if the transfer of water occurs within the exporting region, the sale of water might create employment opportunities in other productive sectors (e.g., industrial, trade) over time (Howe & Goemans, 2003).

Contrary to the results of Whited (2010), Arriaza *et al.* (2002) observed a slight increase in employment opportunities in the agricultural sector in El Bajo Guadalquivir basin, Spain. The impacts on outputs can be positive or negative, depending on the economic sectors participating in the water market (Koopman *et al.*, 2017). Koopman *et al.* (2017) modelled the impact of water markets on the outputs of different productive sectors and verified that the agricultural sector obtained the highest increase in its outputs in a market with the manufacturing and public water supply sectors. However, the manufacturing sector performed best when the public water supply sector was excluded from the model (Koopman *et al.*, 2017).

3.2. Social impacts

The water market can promote equity in water allocation and provide water access for emerging farms (Thiam *et al.*, 2015). Such farms are generally small and do not have water extraction mechanisms and access to irrigation benefits due to the government failure to allocate water (Mukherji, 2007b). Mukherji (2007b) verified that emerging farms in West Bengal, India, had access to irrigation water through the water market and became as productive as sellers' farms. Nevertheless, the author pointed out that these impacts may have been influenced by the characteristics of the area, i.e., abundant groundwater availability, low levels of groundwater development, source of power for groundwater pumping and type of electricity tariff.

On the other hand, water trading can impact users negatively. The transfer of water from Owens Valley to Los Angeles is an example of unfair distribution of the benefits of trade (Libecap, 2005). Where the capital for the implementation of water extraction mechanisms is scarce and concentrated, a monopolistic power of water sellers may arise, leading to conflicts between sellers and buyers (Mukherji, 2007a). As reported by Mukherji (2007a), government regulation of water prices in Mohanpur village, India, was needed to alleviate conflicts and promote equity.

Water trading can also affect access to water rights. Romano & Leporati (2002) verified that the implementation of a water market in Chile favored the allocation of water rights to users with social and economic influence. Although the number of water rights in the region has increased over the years, their distribution has been unequal, as the participation of peasants has decreased significantly (Romano & Leporati, 2002). In addition, peasants obtain access to water primarily through claiming original rights and participate in the market mainly as sellers with weak bargaining power (Romano & Leporati, 2002). Budds (2004) have detected that power and economic inequalities between large landowners and landless peasants in La Ligua and Petorca Valley, Chile, led to the control of water rights by the former and increased the latter's vulnerability to drought.

Several interviews conducted in an Australian rural community revealed that locals believe large landowners and wealthy organizations have an advantageous position in water trading as they have more knowledge about how the mechanism works (Bjornlund, 2003; Hasselman & Stoker, 2017). In the Fortore river basin, Italy, the population has positioned itself against changes in the country's water management laws due to an unequal experience with an auction of water use rights, which has benefited large landowners (Giannoccaro *et al.*, 2011). These reports raised questions about the effectiveness of pure water markets and highlighted the role of government regulations to promote equity (Romano & Leporati, 2002; Mukherji, 2007a).

Water markets can also impact the permanence of rural communities. In an Australian rural community, the current generation of irrigators struggle to stay on their properties due to the replacement of labor by mechanized agriculture (Bjornlund, 2007). Water markets could delay the rural exodus through the sale of water entitlements, although many landowners work in other sectors and only live on the rural property (Bjornlund, 2007).

According to Edwards *et al.* (2008) and Hasselman & Stoker (2017), the feelings of uncertainty, nostalgia and doubt associated with water markets may arise due to the erosion of local community sustainability. If water is reallocated to higher-value agricultural corporations to the detriment of family farming, it can impact the local economy (e.g., through the displacement of the workforce to other regions) and the social functions of the community (e.g., by decreasing school enrollment) (Edwards *et al.*, 2008). The change from traditional production to higher value systems can benefit rural landowners but cause anguish and nostalgia over lost cultural value (Hasselman & Stoker, 2017).

The implementation of water markets can generate corrupt and manipulative behaviors by the action of speculators and large corporations that purchase large volumes of water (Budds, 2004; Hasselman & Stoker, 2017). Users may be unselfishly disrupted by the choice to value water as a commodity over community use (Hasselman & Stoker, 2017). Such effects demonstrate how the logic of the market (i.e., buying and selling) raises the sentiment of winners and losers (Hasselman & Stoker, 2017).

3.3. Environmental impacts

The studies did not assess direct impacts on biological communities, but focused on the impacts on environmental flows, water levels in the aquifer and extreme events. As previously mentioned, a region that exports water through a water market is impacted by lower aquifer levels, and the region that imports it benefits from higher aquifer levels (Murali *et al.*, 2015). The reduction in water consumption caused by water trading can contribute to improvements in environmental flows (Llop & Ponce-Alifonso, 2016). By increasing environmental flows, water markets can assure adequate levels of water in rivers (Grafton *et al.*, 2016) and reservoirs (Knapp *et al.*, 2003; Rey *et al.*, 2016). This impact is prominent during periods of water shortages (Grafton *et al.*, 2016) and when restrict water transfer management rules are imposed (Rey *et al.*, 2016). Connor *et al.* (2013) simulated the reallocation of irrigation water to the environment through a water lease market in Australia to reduce the impacts on ecological demands dependent on flood events. The authors observed that trade could provide environmental benefits during drought scenarios as it can reduce return intervals between moderately large floods.

On the other hand, other studies have identified negative impacts on environmental flows. Water trading can reduce water flows to springs (Gillig *et al.*, 2004) and favor the cultivation of more profitable crops, thus concentrating water consumption in specific areas and periods (Tisdell, 2001; Kahil *et al.*, 2015a). Consequently, natural flow regimes can be altered and no longer meet environmental needs (Tisdell, 2001; Kahil *et al.*, 2015a, 2015b). These studies have not addressed the direct consequences of reduced flows on biological communities or how they can be intensified by climate change. Therefore, the effects of water markets on aquatic ecosystems still need to be appropriately addressed.

4. Conclusions

We review the literature and identified the economic, social, and environmental impacts of water markets. Most studies (41 studies) addressed economic impacts, while social and environmental dimensions were overlooked. The economic impacts focus on greater efficiency in water use, decrease or increase in water consumption and water availability, alleviation of economic losses caused by droughts, reduction or increase in farmers' income, gain or loss of regional net benefits, decrease or increase in the cropland area and productivity, increase or decrease in farms' profitability, and gain or loss of inputs and outputs. The social impacts, cited by 11 studies, are associated with the distribution of benefits, access to water and water rights, conflicts and permanence of rural communities, and users' perceptions. In contrast, the environmental impacts, cited by ten studies, refer to the increase or decrease in environmental flows and water level of the aquifers.

Economic models were the primary method used to estimate the impacts of water markets. However, these models often disregard several factors that can influence the performance of the mechanism, such as the biophysical scenario of the study areas, characteristics of stakeholders, the configuration of public and private agencies, property rights, cultural aspects, household setting, technical and management skills, and transaction and opportunity costs. Several authors have emphasized that the results are intrinsically related to the implementation context, and the modelled impacts would be observed in pure water markets. Therefore, this review is highly influenced by the results of studies on the economic impacts of water markets measured by simulation models.

The literature on the effects of water markets is incipient regarding different research techniques and variety of potential impacts. More studies employing mixed research methods and aimed at the identification of environmental and equity impacts of water markets are necessary. Water trading is a complex and site-specific management instrument. The analysis of its impacts is the first step in considering it an efficient water management strategy.

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