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Review on the Political Economy of Water Reforms in Agriculture

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1.1. The need and difficulties of water reforms

The pressures on water resources have been mounting worldwide with water scarcity becoming a widespread problem in arid and semiarid regions around the world. Global water extractions have climbed from 600 to 3,800 km^3 per year in the last century, which is above the rate of population growth (WWC 2000). The degradation of water resources is a common threat to human water security and environmental biodiversity across the world, which is compensated with large investments to ensure human security in developed countries. However, the threats to natural ecosystems are hardly accounted for (Vörösmarty et al. 2010). The water governance problem calls for water reforms, and these reforms must gravitate around the agricultural sector because the majority of water resources are used for irrigation.

Irrigation is a key component of agricultural production, covering 20 percent of cultivated land and generating 40 percent of the global food production (CAWMA 2007). Irrigation covers 310 million hectares of land with the large acreage located in Asia and America (Siebert et al. 2013). The main countries by irrigation area are India (56 Mha), China (54), the United States (22), Pakistan (18) and the European Union (17). Irrigation demand for water is close to 2,400 km^3 per year, of which 1,700 km^3 are surface water diversions and 700 km^3 are groundwater extractions. The construction of dams for irrigation has been reduced during recent decades, and most dams at present are being built for hydropower (Winemiller et al. 2016). The development of irrigation in recent decades has been based on the enormous expansion of groundwater extractions. Between 1960 and 2010, groundwater extractions from all sectors climbed from 300 to 1,000 km^3 per year pushing depletion up to 150 km^3 (Konikow 2011, Wada et al. 2010, IGRAC 2010).

Water reforms are needed because groundwater extractions and surface water diversions are causing severe water scarcity and water quality problems,[1] with substantial damages to human activities and natural ecosystems. The massive ecosystem damages in basins such as Ganges, Indus, Nile, Yellow, Yangtze, Amu and Syr Darya, Tigris, Euphrates, Murray-Darling, Colorado and Rio Grande (WWAP 2006) call for a reconsideration of the current water management, institutions and policies, leading to far-reaching water reforms. The scale of the global growing water depletion indicates that water mismanagement is quite common, and that sustainable management of basins is a complex and difficult task. The upcoming water governance problem would be especially acute in arid and semiarid regions, where the combined effects of human-induced permanent water scarcity and climate change-induced water scarcity and droughts portend unprecedented levels of water resources degradation in the absence of remediating water reforms.

In the coming decades, climate change is going to be an important challenge for agricultural production. This challenge will be specially difficult to harness because global food demand will almost double by 2050 (Alexandratos and Bruisma 2012), driven by the growth of world population and income. Climate change will increase temperatures and modify the pattern of precipitations, reducing crop yields in both irrigated and rainfed cropland and also livestock productivity because of prolonged or extreme changes in temperature. The biological processes underlying the productivity of plants and animals will be negatively affected by increasing weeds, diseases and pests, along with changes in the development and pollination periods (OECD 2014, USDA 2012).

[1] Water quality impairment results from urban, industrial and agricultural pollution emissions of organic matter, heavy metals, nutrients (nitrogen, phosphorus), pesticides and salinity. In agriculture, pollution loads come from rainfed and irrigated agriculture. In the case of nitrogen emissions in the European Union, the main sources are mostly located in rainfed agriculture areas where crop and livestock production activities concentrate (See figure 1 in Appendix).

Water resources projections using coupled global hydrological and crop models indicate that crop losses from climate change could be in the range of 20-30 percent by the end of the century, depending on the CO_2 fertilization effects (Elliot et al. 2014).[2] Further losses may occur from water resources scarcity in some regions, which will force the reversion of irrigation to rainfed cropland. Changes in precipitation regimes and extreme precipitations will have negative effects on water availability. Precipitations will decrease in mid-latitude and subtropical dry regions, reducing renewable surface water and groundwater resources and escalating the competition for water among sectors (IPCC 2014a).

1.2. Collective action and interest groups in water resources

The management of water resources is characterized by collective action processes. Collective action is driven by the different types of goods and services provided by water, which can be classified as private goods, common pool resources or public goods, but it is also driven by the technologies employed in water utilization which involve economies of scale and indivisibilities resulting in natural monopolies. Also, collective action is needed to account for the externalities linked to the use of water resources in order to avoid market failure, such as ecosystems protection or common aquifer extractions (Rausser et al. 2011).

Group choice in collective action requires coordination and control in the processes of decision making, and the influence of participants shape the decision outcomes. In order to gain influence, individual participants organize in pressure groups to advance their common interests. Political economy models could be used to analyse the conflicts between public and special interests in the design and implementation of public policies. Water reforms involve accommodating the politics of sharing scarce water resources among groups of users with opposite interests. Reforms are the result of negotiations between the main groups of users, and the reform outcomes may not represent the interests of all users or achieve efficient water allocations (Esteban el al. 2017).

Reforms of water institutions and policies imply significant changes in the distribution of power among pressure groups and the benefits of water accruing to them. The consequence is that water reforms could be under substantial political opposition from groups of stakeholders losing power and benefits, who may be able to disrupt the reforms (Dinar 2000). One alternative is to attempt reforms that deal only with the water sector by introducing gradual changes in the status quo. Another alternative is trying substantial water reforms linked to broader economic and structural reforms, while getting the active support of parties in society which are gaining with the reform. But the results of water reforms are uncertain because of the interplay among pressure groups, and because of the limited knowledge on the interactions between human and biophysical processes (Bucknall et al. 2007). In any case powerful interest groups will try to influence the political decision process in order to get more favourable outcomes.

1.3. Water reforms and agriculture

Recent political and institutional water reforms have been triggered by pressures from water scarcity and water quality problems in both developed and developing countries. Major water reforms have been undertaken in Australia, the European Union, the United States, Israel, South Africa, Turkey, Chile and China, among others. In agriculture, the approaches to water reforms recommended by international organizations have been shifting from farmers training and investments in modernization, to transfer of responsibilities from the government to local farmers associations, to creation of river basin organizations, and to privatization and encouragement of water markets.

Reviewing the approaches underlying water reforms during recent decades, Merrey et al. (2007) identify three successive main approaches to water management: state institutions, water user associations, and

[2] Under representative concentration pathway (RCP) 8.5.

water markets. Since the performance of state-run irrigation systems in some countries was considered inadequate in the 1970s, the approach of farmers participation and transfer of irrigation management was embraced, and later on the approach of water markets gained traction. Meinzen-Dick (2007) indicates that these solution approaches are not “panaceas” for water governance, and that the specific coordination arrangements for water management are related to factors such as the spatial scale of irrigation systems, the availability of storage facilities, and the path dependency of institutional and policy processes. It is recommended that the strengths and weakness of each approach have to be analysed empirically before evaluating their adequate combination for specific reforms of water governance.

There are two important questions related to water scarcity and water quality degradation that are essential for any water reform in agriculture. One is the efficiency issue in irrigation to confront water scarcity, where support for gains in irrigation efficiency have been a common topic among policy makers in the World Economic Forum, the Stockholm Water Week (See Perry et al. 2014) and the Global Forum for Food and Agriculture, and also in international organizations such as FAO (2012), the World Bank (2013) and the World Water Assessment Program (2016). The other question is how to deal with nonpoint pollution from agriculture, which damages the quality of water systems and contributes to greenhouse gas emissions and atmospheric acidification.

Irrigation efficiency could be augmented with investments in irrigation technologies but also through water markets reallocating water to efficient irrigation areas. The issue on irrigation efficiency is the following: irrigation efficiency gains at plot and district levels could led to more evapotranspiration and less return flows, resulting in lower stream flows at basin level. This fall in basin stream flows have been observed in Spain and Australia following the multibillion dollar investments in irrigation technologies by both countries in the past decade. This has been called lately the “rebound” or “Jevons paradox” effect, although the externality problem has been identified for a long time by water economists, since the early contribution of Hartmann and Seastone (1965).

Nonpoint pollution from agriculture is a serious problem resulting in nutrient emission loads into water media, and emissions of greenhouse gases and ammonia to the atmosphere. The fact that there are many pollutants coming from a large number of sources, following transport and fate processes along different paths, and damaging ecosystems and human activities through ambient pollution in water systems and the atmosphere, results in a very high level of complexity for the design and implementation of abatement policies. Source emissions and pollution pathways to receptors are not observable and highly stochastic, preventing pollution monitoring or even predictions with models. The consequence is that nonpoint pollution abatement becomes a “wicked challenge” for economic instruments, and pragmatic solutions require the inclusion of command and control and institutional instruments, or combinations of instruments (Shortle and Horan 2017).

Water markets and water pricing are considered promising economic instruments for water allocation and pollution abatement in agricultural water reforms. This paper reviews how economic instruments have been implemented in the water reforms undertaken in Australia, the European Union, Israel and the United States, and how they have been combined with other types of instruments such as command and control and institutional instruments. The outcomes from these reforms are examined for both water quantity and water quality, evaluating their main accomplishments and setbacks in order to gain useful lessons for future water reforms in agriculture.

2. Water Reform in Australia

2.1. The stages of water reform and the development of water markets

The water reform in Australia was prompted by the escalating growth of water use in the Murray-Darling basin, with water diversions doubling from 6,000 up to 12,000 Mm^3 between the 1960s and the 1990s. This mounting pressure created serious problems of water scarcity and environmental damages in the basin. The first arrangement was the Murray-Darling Basin Agreement in the late 1980s between the states and the federal government to control the unsustainable growth in diversions by establishing a cap on diversions. Then, there was an agreement in 1994 setting the framework of the water reform by the Council of Australian Governments. The reform was based on establishing water entitlements by separating water rights and land ownership, and achieving volumetric, metered and tradable water rights. The implementation of this agreement was tied to the National Competition Policy in the form of incentive payments to states.

The Millennium drought (1996-2009) motivated the renewal of the water reform through the National Water Initiative of 2003, aiming at increasing the efficiency of water use. The initiative established the management of water through water markets and planning in order to optimize the value of water, while protecting the environment. There were significant financial incentives to unbundle water entitlements from water use approvals, develop water markets, and provide water for the environment.

The continuing drought led to the National Plan for Water Security in 2007 which expanded the scope of reform. The plan provided AU$ 6 billion for water efficiency investments and AU$ 3 billion for environmental water purchases, in exchange for transferring water management from states to the federal government. The Water Act was passed in 2007 establishing the Murray-Darling Basin Authority in charge of preparing the basin plan, and creating the Environmental Water Holder for managing environmental water. The basin plan approved in 2012 is being implemented, and the key elements are sustainable diversion limits, setting environmental flows based on the trade-off between economic and environmental impacts, the management of water quality and salinity, and the enhancement of water markets (Hart 2016a).

The program Water for the Future approved in 2008 expanded the investments in irrigation technologies from AU$ 6 to 11 billion, and maintained the water buyback of AU$ 3 billion for the environment. At the beginning of 2016, environmental water recovery estimates are around 2,000 Mm^3 of the 2,800 Mm^3 planned, with 1,200 Mm^3 coming from $AU 2.3 billion purchases of environmental water (out of the 3 billion planned), and 800 Mm^3 in water savings from irrigation investments of $AU 3.1 billion (out of the 11 billion planned) (Australian Government 2015, Hart 2016b).

2.2. Achievements and challenges from water markets

2.2.1. Welfare gains and confronting the Millennium drought

Two important characteristics of the water reform in Australia that explain the development of a fully active water market have been: first, water entitlements separated from land that give access to a share of available water, and second, the monitoring and enforcement of these volumetric shares. The result is that irrigation water has been converted from a common pool resource to a private good that can be traded, generating welfare gains from enhanced private profits.

Water trading in agriculture covers mostly temporal (annual) and some permanent trading, with water moving from low profitable crops such as pasture and cereals to high profitable vegetables and vineyards. There are also substantial potential gains from water trading between rural and urban areas.

Water markets in Australia were essential to confront the recent Millennium drought. Despite the fact that water availability fell by 75% during the 2006-2009 drought period, water markets reallocated water from low to high value crops. The benefits of this water trading have been estimated close to AU$ 1 billion per year, with one half of water allocations being traded in 2006-2007 (Connor and Kaczan 2013).

2.2.2. Water scarcity and water quality problems

Water markets have resulted in negative impacts on environmental flows (Connor and Kaczan 2013, Young 2010). The first reason is that water markets introduce incentives for selling water that was not used previously by water right holders. The second reason is the irrigation efficiency externality mentioned before, since water trading takes place from low to high efficient irrigation districts and results in increased evapotranspiration and reduced return flows to the basin.

This irrigation efficiency externality from water trading is exacerbated in the Australian water reform by the large public investments planned of AU$ 11 billion in irrigation technologies, which would further aggravate the problem of falling irrigation return flows to the basin. The gains in irrigation efficiency are confirmed by Bryan et al. (2009), who indicate that irrigation investments have resulted in an expansion above 10% of the irrigated acreage since 1995, while water diversions have been reduced.

The claim by the government of 800 Mm^3 in water savings from irrigation investments is questionable, given that efficient irrigation technologies not only increase water consumption but they may increase also water withdrawn and water applied. The fact that efficient technologies convert a larger share of applied water to consumed water results in lower cost of consumption, so farmers respond by increasing water consumption and irrigated acreage, and changing the crop mix to more water demanding crops (Scheierling and Treguer 2016) .

Another effect of water markets has been the increase in groundwater use, since the cap on surface diversions induced higher groundwater extractions. Official sources estimate the additional extractions at 500 Mm^3/year during the first half of the 2000s (MDBC 2008), although estimates based on the GRACE NASA satellites are several times higher during the Millennium drought (Leblanc et al. 2009). Holley and Sinclair (2016) indicate the need for enhancing the compliance and enforcement practices of reform, especially in groundwater extractions.

The Australian water reform includes a water quality and salinity management plan. The purpose of the plan is to ensure that stream flows are adequate for irrigation, urban and industrial water uses, and for sustaining aquatic ecosystems. The main goals are the reduction of salinity loads and the preservation of stream flows. The plan is a continuation of the previous salinity management strategy dealing with salinity in the basin. An important effect of the large public investments in irrigation technologies is their contribution to the abatement of salinity and nutrient pollution loads, since the gains in irrigation efficiency reduce fertilization and the return flows that drag salinity and nutrients to water streams.

2.3 Assessment of reform implementation in agriculture

The water reform is Australia has been successful at halting the unrelenting growth of water diversions in the Murray Darling Basin that took place between the 1960s and the 1990s. The approach taken has been the establishment of water markets, which have been essential to confront the recent Millennium drought. One important lesson is that after the reform water trading is an effective way to reallocate water and get optimal private profits outcomes.

The setting of water markets has not been easy because it has required the support of the key groups of interest. This support has been obtained through the commitment of very large public funds in order to make water markets work: payments to states to support the introduction of water markets and payments in exchange of transferring management powers to the federal basin authority, payments to farmers for irrigation investments, and payments to buy back water for the river. The implication here is that the Australian approach involves substantial public funding that could be unaffordable for less wealthy countries.

Another important lesson from the Australian reform is that water markets are based on trading in water diversions instead of trading in water consumption. This leads to less water in the basin, since evapotranspiration increases when moving diverted water to more efficient irrigation technologies.[3] One option to avoid this would be to adjust allocations in water plans by reviewing the impact of water trading in the stream flow of local watersheds. But the logic behind the choice in Australia is that a market based on water consumption will have much higher transaction costs that would limit the potential benefits of water trading.

A final lesson is derived from the effects of the large public investments in irrigation technologies that reduce irrigation returns and stream flows in the basin. This effect could be corrected by decreasing the water allocated to modernized irrigation districts in order to compensate for the fall in returns, although such reductions in allocations will be opposed by farmers. A major positive effect of irrigation modernization is the reduction of fertilizers use and the fall of return flows leading to the considerable abatement of nutrient and salinity loads into water streams.

3. Water Reform in the European Union

The scarcity and degradation of water resources is an important environmental problem in Europe. The use of water by the different economic sectors creates water scarcity in southern regions, and a widespread water quality degradation from nonpoint and point pollution all over Europe. However, the considerable pollution of rivers in the past has been clearly improved in recent decades as a consequence of reduction in organic matter loads, the use of detergents free of phosphates, and the operation of wastewater treatment facilities in urban centers. Water scarcity is serious in southern countries, with a strong water demand during summer for irrigation but also for tourism. Despite regulations and large investments in urban and industrial water treatment plants, water quality degradation remains high in many river basins because the nonpoint pollution loads from agriculture are not decreasing.

The initial European legislation on water resources was passed in the 1970s including the so-called Dangerous Substances, Surface Water and Drinkable Water Directives. But the major water reforms in the European Union (EU) in recent decades are the result of the main water regulations that include the Urban Waste Water Treatment Directive, the Nitrates Directive, both of 1991, and the Water Framework Directive of 2000. The emphasis of these European regulations have been on water quality rather than on water quantity issues.

Early legislation followed emission standard or water quality approaches for pollution abatement. In the 1980s, the European governments recognized the need to address industrial, urban and agricultural pollution together. The consequence was the adoption of the Urban Waste Water Treatment and the Nitrates Directives, and the preparation of a framework instrument establishing the principles of sustainable water policy leading to the Water Framework Directive.

[3] For any crop mix, efficient technologies increase the share of applied water to consumed water which reduces the costs of consumption, leading to the expansion of water consumption and irrigated acreage. For highly profitable crops (e.g. greenhouse production), the pressure to expand water consumption is really strong. Trading in water consumption will maintain basin flows, but trading in water diversions reduce basin flows.

3.1. The Urban Waste Water Treatment and the Nitrates Directives

The Urban Waste Water Treatment Directive required building depuration plants with secondary treatment plants or else tertiary treatment plants in special sensitive areas. The investments in urban treatment plants have been large, above 200 billion Euros, achieving a significant reduction of organic matter and nitrogen and phosphors emission loads into water media resulting in lower environmental damages to aquatic ecosystems. The central and northern European countries have already depuration plants with tertiary treatment, while countries in the south of Europe, together with France, Belgium and the UK, have depuration plants with secondary and tertiary treatment. The Eastern European countries entered the Union in 2004, and they are in the process of completing the requirements of the Directive.

The Nitrates Directive aims to protect water quality by preventing nitrates from agricultural sources to pollute ground and surface waters. The main measures are the identification of vulnerable zones to nitrate pollution, good farming practices, and the setting of fertilization limits. The purpose is the abatement of nitrate pollution in water bodies and mitigation of GHG emissions generated by excessive nitrogen fertilization and manure surplus. However, the achievements of the Nitrates Directive during the last two decades are questionable (Albiac 2009), as can be seen in figure 1 in the Appendix showing the strong unbalance of nitrogen in soils. One problem with the Directive is the setting of homogeneous measures across the different European regions, which is questionable since the magnitude of the nitrogen pollution loads in soils is vastly different among regions.

3.2. The Water Framework Directive

The Water Framework Directive intends to achieve good ecological status for all water bodies, through water pricing policies, the combination of emission limits and water quality standards, and the participative management of basins. The main phases of the WFD have been the elaboration of the basin management plans and the programs of measures, and the introduction of water pricing policies and the programs of measures to reach the environmental objectives in 2015, completing the first management cycle.

The European Commission (EC 2015) indicates that there is progress towards addressing the challenges faced by water resources. However, there is a long way to go before the quality of all EU waters is good enough to reach good ecological status for most water bodies. Water policy shortcomings are important, and about half of EU surface waters have not reached good ecological status in 2015. Also, the chemical status of almost half water bodies is unknown because of the deficient monitoring. This lack of information prevents the design and implementation of reasonable measures to achieve good ecological status or even to make improvements in water bodies.

3.2.1. The program of measures: water pricing as key instrument

The program of measures is the instrument to achieve the good ecological status objective in each basin plan, and an essential component of the program is water pricing. The Directive introduces the principle of water prices close to full recovery cost, considering also that water pricing will improve the efficiency in the use of water. The full cost must include abstraction, distribution and treatment costs, and also environmental costs and resource value. The principle of cost recovery is the key element in the policy analysis advocated by the Directive (EC 2012, Treyer and Convery 2012). The increase in water prices up to recovery cost is a very interesting measure in urban networks where water has private good characteristics, and water demand responds to water prices leading to a higher efficiency in water use.

In irrigated agriculture, water pricing is a quite challenging measure because irrigation water is mostly a common pool resource. Water pricing could be used in the long run to recover costs and to indicate basin scarcity. However water pricing doesn’t seem feasible in irrigation to reallocate water in the short run, because during droughts the water price charge on farmers would be so high to balance supply and demand, that water pricing becomes politically unfeasible. During strong droughts in irrigated areas, institutional or command and control instruments seem much better than pricing for short run water reallocation. The use of water markets during droughts is also much better than water pricing, because farmers can sell water and maintain income rather than losing significant income by paying large water price hikes (Albiac et al. 2016).However, the establishment of water markets involves important economic and institutional costs.

Scheierling and Treguer (2016) indicate that water reallocation can be done either with water pricing or with quantity-based measures. They find that the problem with water pricing in irrigation is that irrigation demand is price-inelastic, so small reductions in irrigation would require large price increases resulting in large income losses to farmers. Even charging high water prices would not result in real water savings when return flows are important. Quantity-based measures or quotas can achieve an efficient allocation, such as using water markets to exchange quotas from low to high value water uses. However, some other reallocation mechanisms are common in most basins worldwide and in Europe: these are informal water exchanges between farmers, transfers based in priority of use during droughts, and transfers by institutional decisions taken by basin authorities or other water authorities.

Summing up, water pricing is a good instrument for water reallocation in urban and industrial networks, but not so good for irrigation. Therefore water pricing is paramount in central and northern Europe where water demand is largely urban and industrial, while water pricing is not so good reallocation instrument for irrigation in southern Europe which is the main use of water.

In the case of Spain, the basin plans from basin authorities indicate that water prices for irrigation are close to financial supply costs in basins, covering 90% in the Duero basin, 80% in the Ebro and Jucar basins, and 70% in the Guadalquivir basin. However, the environmental costs and the resource costs (opportunity costs) are not recovered.

3.2.2. The problems of nonpoint pollution and water scarcity in agriculture

The Water Framework Directive includes the OECD's "polluter pays" principle as the suitable rule for pollution, and the principle is applied in urban and industrial point pollution. But the principle cannot be applied to pollution from agriculture, since pollution loads from agriculture are nonpoint emissions.

Agricultural nonpoint pollution is addressed by the Nitrates Directive. Farmers are required to keep nitrogen balance books, and enforcement is based on inspections drawn by chance, where noncompliant farms are penalized in their agricultural policy subsidies. However, control is limited to cultivation areas located over aquifers or streams declared officially vulnerable to nitrate pollution. Outside vulnerable zones, an organic fertilization limit is established evenly for all European countries at 210 kgN/ha, with no limits on synthetic fertilizers and no rigorous control. The efficacy of these control mechanisms remains to be seen because it ignores whole basins, the substitution of synthetic fertilizers by manure, and polluting crops not receiving subsidies, such as vegetables or fruit trees. No consideration is given to the biophysical heterogeneity of farms, the pollution transport and fate processes, the interaction among pollutants, or to the spatial distribution of ecosystems and the ensuing disparity of environmental damages by location.

An important issue to be addressed for solving the nitrogen unbalance in Europe is that livestock manure contains 7 million tN that could be used to substitute a considerable part of the 11 million tN contained in synthetic fertilizers. If all manure was used for crop fertilization, the use of synthetic fertilizers would decrease curbing the entry of nitrogen in soils and reducing nitrogen loads into water bodies, which are estimated at 4 million tN in Europe (Seitzinger et al. 2009). Manure recycling will also reduce nitrous oxide emissions contributing to the mitigation of GHG emissions, but it would require a high level of cooperation and organization among stakeholders. There are also several more costly manure treatment technologies based on biological processes which have high investment and operating costs.

The implication for the Water Framework Directive is that nonpoint pollution measures can not follow the "polluter pays" principle, since a single pollution price implicit in taxes or permit markets doesn't exist given the complexity of the biophysical environment. Shortle and Horan (2017) recommend regulatory measures mixing various types of incentives, rather than economic incentives alone.

Water scarcity is a common problem in arid and semiarid regions with irrigated agriculture. In the EU, the countries with the larger irrigated areas are Spain, Italy, France, Greece and Portugal, and the rank by water diversions are Spain (21,000 Mm^3), Italy (20,000), Greece (3,900), Portugal (3,400) and France (2,400). The share of advanced irrigation equipped with drip systems is very high in Spain (50%) and Greece (40%), and this technology is linked to high value crops such as fruits and vegetables. Drip irrigation in Italy, France and Portugal is much lower, because irrigated crops are mostly field crops under surface or sprinkle irrigation technologies. In these arid and semiarid regions of southern Europe, the vulnerability of irrigated agriculture to climate change is expected to be strong (IPCC, 2014b), with reductions in freshwater supplies and rising water demand (20-40% increases for irrigation), and more frequent and intense droughts (Lehner et al. 2006, Jimenez et al. 2014). Irrigation adaptation to climate change in southern Europe has become an important objective in European water and agricultural regulations (EC 2009 and 2013).

The most important initiative in Europe related to irrigation has been the Spanish National Irrigation Plan 2002-2008. The plan has covered the modernization of 1.5 million hectares with investments of 6 billion Euro, including 3 billion in public subsidies so it was a cost-share program with farmers. The plan has contributed to a significant reduction of nutrient and salinity pollution loads. However the plan has not contributed to the reduction of water scarcity in basins, since the gains in irrigation efficiency has resulted in the fall of irrigation returns and diminished water flows in basins.[4] Other initiatives to expand water supply have been the construction of desalination plants (1,200 Mm^3/year capacity) and the reuse of treated wastewater, with irrigation using around 400 Mm^3/year from both sources.

3.3. Basin authorities in Spain and France

Before the Water Framework Directive, the only countries in Europe with fully developed basin authorities were Spain and France. In Spain, water management is based on water authorities in each basin, which elaborate and implement the river basin plans. Federal basin authorities called hydrographic confederations are in charge of interstate basins, and state governments are in charge of urban supply and wastewater treatment, agriculture, land planning and environment protection. The basin authorities are organized around the governing and stakeholder boards, and an important feature is the involvement of stakeholders, which include water users, public administrations, farmers' unions and environmental groups. The stakeholders' representatives are present in all governing and participation bodies at basin scale, and run the watershed boards at local scale. The advantage of having the stakeholders taking decisions in the basin authority is that the implementation and enforcement of decisions is carried out smoothly.

The basin authorities in France are called water agencies. The agencies were created at the end of the 1960s as financing agencies for dealing with investments of water infrastructures in basins. With the Water Law of 1992, the water agencies became responsible for the management of water resources and the elaboration of basin plans. In each water agency, there is a basin committee with representatives from users, and local, regional and national authorities. This committee prepares the basin plan, set the taxes

[4] See the detailed studies by Lecina et al. (2009) and Jimenez and Isidoro (2012) for irrigation districts in northeastern Spain, based on field measurements before and after irrigation modernization.

levied on water, and decides the water investments. There is also a national water office in charge of generating information of water resources, and supporting basin planning and implementation of measures. Two key principles of the water agencies are the user-pays principle and the polluter-pays principle. The funds collected with taxes are used for water investments, following the rule “water pays for water”.

3.4. Assessment of reform implementation in agriculture

The main water reforms in the European Union have been the Urban Waste Water Treatment Directive and the Nitrates Directive in the 1990s, and the Water Framework Directive in the 2000s. The results of these water reforms show that there are implementation challenges remaining in some cases, but also possible inadequate design in others.

The large investments in wastewater treatment plants have resulted in a considerable abatement of organic matter and nutrients point pollution, and the implementation of the Urban Waste Water Directive has been quite successful. The Nitrates Directive achievements are more questionable since this regulation has failed during 25 years to significantly curve the entry of nitrogen in soils, which represent the major contribution to the 4 million tN of pollution loads into European rivers. Better implementation of the Nitrates Directive is possible as the case of Denmark shows. Implementation has been based on fertilizer accounting, land-based manure limits and regional zoning, reducing nitrogen surplus from 170 to 100 kgN/ha.

The Water Framework Directive goal is to achieve good ecological status for all water bodies. The main instrument is full recovery cost through water pricing. Water pricing is a very interesting measure in urban and industrial networks, but water pricing is a quite challenging measure in irrigated agriculture. Water pricing in irrigation doesn’t seem very feasible to reallocate water in the short run when there is scarcity. However, other reallocation mechanisms are common in Europe such as informal water trading among farmers, water transfers based in priority use during strong scarcity, and institutional decisions on water transfers by water authorities. The implication is that water pricing is an appropriate instrument in central and northern Europe where water is mostly used in urban water networks, but water pricing is not the better instrument for water reallocation in southern Europe where irrigation is the main use of water and other instruments such as water markets and institutional approaches should be considered.

The “polluter pays” principle advocated by the Water Framework Directive is suitable for point pollution, but can not be used to address agricultural nonpoint pollution. The Nitrates Directive has not significantly reduced nitrogen pollution loads into European rivers, and new approaches to curb agricultural nitrogen emissions could be needed.

One option would be to implement the substitution of synthetic fertilizers by manure, lowering the entry of nitrogen in soils and the subsequent pollution of water streams. Another more costly option would be investments in manure treatment facilities. The abatement measures should address the worst polluting spots and be tailored to local conditions.

Regarding water scarcity, the only European initiative has been a communication on water scarcity and droughts setting up voluntary plans not legally enforceable.[5] The main irrigation policy initiative in recent years has been the 6 billion Euros Spanish National Irrigation Plan to modernize 1.5 million hectares, which has reduced nutrient and salinity pollution loads. The government claims that water abstractions have been reduced by 14% (around 3,000 Mm^3), although the effects have been surely a fall in basin flows because of the increase in irrigation acreage (almost 10%) and higher evapotranspiration by crops leading to falling return flows.

[5] Communication on Water Scarcity and Droughts, approved in 2007.

The countries with more developed basin authorities in Europe are Spain and France. The water management approach in Spain is institutional, with stakeholders being involved in all their governing bodies, and also running the local watershed boards. In France, basin authorities include representatives of users and local, regional and national authorities. Their main tasks are setting the water taxes and deciding the investments, following the rule "water pays for water". However, the specific contribution of developed basin authorities to the improvement of water management has not been analysed.

4. Water Reform in Israel

4.1. The substantial pressures on water resources

One important feature of water resources in Israel is the very strong pressures that human activities have on water systems. The acute water scarcity in the country is shown by the very small annual water supply per capita which is below 200 m^3. Renewable water supply is around 1,400 Mm^3 per year, and the three main water sources are Lake Tiberias, the Mountain aquifer and the Coastal aquifer. Water use is around 2,100 Mm^3 per year, divided between 1,100 Mm^3 for irrigation and 810 Mm^3 for urban and industrial uses, and almost half of the water used in agriculture is reutilization from urban treated wastewater (Becker 2013). The unbalance between water supply and demand escalated between 1980 and 2000, and was covered by the depletion of Lake Tiberias and the aquifers. After 2000, annual water supply has been augmented by the massive use of so-called marginal sources: treated urban wastewater supplying 500 Mm^3 to irrigation, and seawater desalination plants supplying another 500 Mm^3 to urban and industrial uses.

4.2. Evolution of water policies and management

Water has been always an important issue in Israel, and the growing water scarcity has led to intense debates on the management and policy reforms needed to address water problems. The first stage in water policies was the development of irrigated agriculture and urban settlements through the construction of a national water system. The so-called national water carrier was completed in the 1960s, connecting Lake Tiberias and the main aquifers to irrigation and urban demand areas.

The second stage started after development of the main water sources, and the policy focus moved towards the management of the available resources. The Water Law of 1959 declared all water resources public owned, and established a command and control regime. This regime was based on permits for all water surface diversions and groundwater extractions, setting the amounts to be taken from each water source and delivered to each use, full metering along the water network including supply, distribution and end user nodes, and central monitoring of the water system (Feitelson, 2013). However this command and control system could not avoid the continuous growth of water abstractions for irrigation and urban uses, and the resulting depletion of water sources. The agricultural interests were successful in avoiding demand management measures to reallocate water from irrigation to urban and industrial uses. The water scarcity led to investments in advanced irrigation technologies coupled with changes towards high profitable crops, and the progressive use in irrigation of recycled water from urban wastewater treatment plants.

The following stage of water policies has been the result of the strong depletion of Lake Tiberias and the aquifers, and the threats from the droughts in the late 1980s and 1990s. The water policy proposals in the 1990s included water pricing up to full-cost recovery, allocation of environmental flows for ecosystem protection, water resources privatization, and seawater desalination. Two important developments after 2000 have been the generalization of treated wastewater in irrigation, and the decision to invest in large desalination plants. The urban water sector has been reformed with new corporations substituting the municipal water supply and wastewater treatment companies, and also with the privatization of the national water company. The private sector is now in charge of water supplying, wastewater treatment, and seawater desalination (Feitelson, 2013).

4.3. Command & control and economic instruments

Water management in Israel has two important characteristics for agricultural, urban and industrial uses: public ownership of water and a national conveyance systems linking water sources in the north to water demand areas in the rest of the country. The command and control management system has been working for irrigated agriculture, where there is a combined system based on administrative quotas and water pricing payments based on the level of quota utilization. In the urban and industrial sectors there are no quotas on consumption, and the allocation mechanism is water pricing.

The command and control instrument has been used in recent decades for the reallocation of freshwater from irrigation to urban use. Not only the use of irrigation water has been reduced by 30% since the mid 1980s, but also almost half of the present irrigation use is supplied with treated urban wastewater. This command and control feature of water management has facilitated the reallocation of freshwater from agriculture to urban and industrial users, in comparison with the difficulties and costs of undertaking water reallocation in a decentralized water system based on private water rights (Kislev 2013).

The reform of water management during the 2000s has been focused on the urban sector, with the overhaul of the water supply and sewer companies. The water authority (called the Authority of Water and Sewage) was created in 2007 to accomplish the reform, and US$ 0.5 billion in public incentives have been provided by the government.[6] The new corporations cover the vast majority of municipalities and urban population. The water and sewer tariffs are now linked to the costs of providing the services, which fully cover at present the water investments such as the new desalination plants. The urban tariffs have increased steeply by almost 50% in recent years up to around \$US 3/m^3, with a higher block rate for over quota consumption. The water authority proposed different urban tariffs linked to the costs of each corporation, but due to political pressures the water tariffs charged by corporations are the same for all urban consumers.

In agriculture, more than half of the water used is provided by the national water system, and the rest by the farmers' own sources. Farmers have upper limit irrigation quotas allocated by the administration. Farmers buying from the water system pay tariffs in block rates varying with the percentage of demand over the quota. The tariffs are around US\$ 0.60/m^3 for freshwater, and around US\$ 0.25/m^3 for recycled water which covers 65% of the total water bought by farmers. Farmers using their own resources pay extraction levies at around US\$ 0.20/m^3. Urban users cross-subsidize irrigation water tariffs (around US\$ 0.25/m^3) although irrigation tariffs for freshwater are planned to increase up to US\$ 0.80/m^3 in 2016 (Kislev 2013).

4.4. Assessment of reform implementation in agriculture

The development of the water infrastructure in Israel was followed by the establishment of a command and control regime. Permits were issued for all water abstractions, with central monitoring of surface diversions, groundwater extractions, and all water deliveries. The first water reform was prompted by the growing water abstractions and the resulting water scarcity. The reform measures involved investments in advanced irrigation technologies and in wastewater treatment plants, and the progressive introduction of recycled water in irrigation. Despite this water reform based on investments in water technologies, water abstractions for agriculture continued growing creating a serious problem of depletion in the water sources.

[6] Using the exchange rate 1 US$ = 3.7 Shekel

In the 1990s, the unrelenting depletion of Lake Tiberias and the aquifers continued and became critical during severe droughts events. The result has been a new water reform undertaken after 2000 based on full cost water pricing, generalized substitution of freshwater for recycled water in irrigation, the privatization of the water supply and sewer companies and the national water carrier, and a strong program of seawater desalination. As of 2016, farmers are paying the full financial cost of freshwater at US$ 0.80/m^3, without further cross-subsidization from urban users.

The outcomes of this reform have been a curtailment of water abstractions from Lake Tiberias and the aquifers easing the pressure on these water sources, the expansion of desalinated water up to 500 Mm^3, and the reallocation of freshwater from irrigation to urban use. The demand of irrigation since 1985 has been reduced by 300 Mm^3 and most of the irrigation demand is now covered with recycled or marginal water, while urban and industrial demand has increased by 200 Mm^3.

The command and control system in irrigated agriculture has been essential for reallocating freshwater from agriculture to urban and industrial uses. If instead of command and control in irrigation, the water institutions were decentralized and based on private water rights, the difficulties and costs of water reallocation among sectors would have been quite substantial.

Water reforms have resulted in considerably higher water prices, and urban consumers are protesting the high tariffs and pondering the impacts on disadvantaged households. In agriculture farmers are also protesting the high tariffs, despite the agreement for lower tariffs in irrigation. The freshwater tariff for irrigation (US$ 0.80/m^3) is substantially below the urban tariff (US$ 3/m^3). However, most of the irrigation water is recycled water or own resources paying lower tariffs.

5. Water Reform in the United States

5.1. Water institutions and policies

The water institutions in the United States are based on the legal riparian and appropriation doctrines for water quantity, and on the legislation of the Clean Water Act of 1972 and the Safe Drinking Water Act of 1974 for water quality. The riparian doctrine is applied in the Eastern United States having an adequate supply of water, where water bodies are considered private water that can be reasonably used by the owners of bordering lands. The prior appropriation doctrine is applied in the western United States where water is scarce and the rule for water rights is “first in time, first in right”. Water policies in the west were focused in the past on the development of water supplies mostly for irrigation, with massive investments in water works that supported the growth of economic activities and population. Water management is the responsibility of states, which are also in charge of implementing federal regulations on water

The management of river basins by basin authorities has not been developed in the United States. The only institutional arrangements have been some interagency committees and river basin commissions without policymaking authority, and the federal and interstate water compacts. Water compacts are agreements among states for water allocation in interstate rivers. There are twenty water allocation compacts and the first established was the Colorado River compact in the 1920s. Studies on river basin plans were undertaken in the 1930s but the only outcome was the Tennessee Valley Authority, given that there is no federal authority on interstate basins and states have the control of water in their territory. Another attempt to elaborate basin plans was made by the Water Resources Council, which was created in 1965 and eliminated in 1982 (Spulber and Sabbaghi 1998). The arrangements for water plans are undertaken by states, mostly for water quality management plans and some supply water plans such as the California’s water plan.

The policy emphasis on water supply development changed in the 1970s, and the main trust of water policies in the United States during recent decades has been on water quality. Substantial water reforms were introduced to address water quality problems through the Clean Water Act and the Safe Drinking Water Act. Under the Clean Water Act, the Environmental Protection Agency (EPA) regulates the discharge of pollutants from point sources and the treatment of municipal and industrial wastewaters, with states enforcing the regulation. The deadline for wastewater secondary treatment plants was initially set in 1977, with public funding around US$ 5 billion annually between 1972-1982 and reduced to 2.5 billion after 1982. The accumulated public funding for wastewater treatment plants has been around US$ 90 billion. Under the Safe Drinking Water Act, the EPA regulates the public drinking water systems with states enforcing the regulations. The accumulated public funding has been around US$ 15 billion, although substantial spending is needed to address the aging urban infrastructure. The investments needed for the next twenty years are estimated at 320 billion dollars for wastewater and 340 billion for drinking water (Copeland and Tiemann, 2010) .

5.2. Addressing water scarcity and water quality in agriculture

Irrigation water use is around 190 km^3 per year, which represents 65% of water consumptive uses (without cooling). Irrigation withdrawals are coming from surface water diversions (60%) and groundwater extractions (40%) (Maupin et al. 2014). The main irrigation areas are located in the western and central plains states, creating strong pressures on the water resources of states with massive irrigation withdrawals such as California, Idaho, Colorado, Arkansas and Texas. The consequence of excessive water abstractions is the fall in stream flows and groundwater tables, where major rivers such as the Colorado and Rio Grande have become closed water systems, and groundwater overdraft is accelerating in the High Plains, Gulf Coast and Central Valley aquifers for a total groundwater depletion close to 24 km^3 over 115 km^3 of annual extractions in the country (Konikow, 2013). Environmental flows are not considered in the water allocation system, and the only provision for environmental flows is derived from the Endangered Species Act. During droughts this approach fails to deliver minimum flows to ecosystems, leading to strong conflicts between farmers and environmental interest groups that could result in judicial litigation.

Water scarcity was addressed by the Reclamation Reform Acts of 1982 and 1992 which increased the costs of irrigation while reducing water supplies. Subsidies to irrigation declined and more water was left for the environment. State and local water agencies increased also the cost recovery of irrigation projects. An example of these higher costs is the State Water Project in California which applies full cost recovery with irrigation being only a third of water deliveries because of high prices. In groundwater irrigation, higher energy costs and falling water tables have also increased the pumping costs in the California's Central Valley and the Ogallala aquifers

There has been regulation intended to reduce groundwater depletion. One case is the groundwater legislation in Arizona linked to the Central Arizona Project, with individual allocations to farmers and control of extractions by the state (Colby and Jacobs, 2007). Another recent case is the groundwater legislation passed by California in 2014 requiring the creation of groundwater agencies in stressed basins. The agencies are in charge of elaborating management plans to achieve sustainability in 2040. Failure to comply will be addressed with negotiations where the state can establish the basin plan (Gray et al. 2015). Stakeholders in stressed basins would have also the option of litigation leading to groundwater adjudication (water allocations established by courts).

Agricultural nonpoint pollution is an important source of water quality impairment, and pollution abatement policies have been addressed by the US Department of Agriculture (USDA) conservation programs, such as the Conservation Reserve Program and the Environmental Quality Incentives Program. Funding for conservation programs in the period 2002-2016 has been around US$ 5 billion per year.

5.2.1. Water markets

The interest for water markets started in California during the droughts of the late 1970s and early 1990s, with legislation approved in the 1980s to facilitate trading and with the launch of the state water bank during the 1990s drought. In other western states, there are several permanent state water banks dedicated mostly to protect environmental flows in streams.

In California, water trading has increased since the 1990s, but the level of trading volume at 2,000 Mm^3 is only a small fraction of the 50,000 Mm^3 of total irrigation and urban water use. During the recent drought, the proposal for a state water bank in 2009 failed because of the opposition of exporting regions and environmentalist groups. Water trading is encumbered by the institutional setting, the groups of interest in donating basins and environmental concerns, despite the fact that the potential gains of water trading in agriculture during the current drought has been estimated at US$ 1.7 billion for the year 2014 (Howitt et al. 2014).

The difficulties of water trading arise from the norms and regulations dealing with third party effects. This problem of water market failure is managed through highly politicized decisions, and the consequence is a very limited development of water markets (Hanak 2015). The transaction costs issue has been examined by Regnacq et al. (2016), and the empirical evidence in California demonstrates the importance of distance and institutional impediments in water trading. While one part of transaction costs are a legitimate protection of third party interests, especially the environment, the other transaction costs could be reduced to facilitate trading. The development of water markets requires enhancing the information on water trading, by clarifying the trading rules and market transactions and also by providing better information on the water system (Escriva-Bou et al., 2016)

5.2.2. Nonpoint pollution abatement

The USDA and the states are responsible for controlling agricultural nonpoint pollution, given that the Clean Water Act does not regulate nonpoint pollution. Despite the large public funding in agricultural nonpoint pollution policies, there is no clear general improvement of water quality in basins. More than 5,000 water bodies are impaired by nutrient pollution from agriculture, among them major aquatic ecosystem assets such as the Chesapeake Bay, the Great Lakes, the Gulf of Mexico and the Florida Everglades (Ribaudo 2015).

As already indicated, agricultural nonpoint pollution is linked to an important problem of complexity and lack of information and knowledge. Under these circumstances nonpoint pollution cannot be addressed by economic instruments: not only the single pollution price rule that could be established trough taxes or permit markets fails because of the complexity of the physical environment, but also because the economic and ecological evaluation of options becomes very difficult. (Shortle and Horan, 2017)

Nonpoint pollution from agriculture is addressed by the USDA conservation programs. Funding since 1996 has been around US$ 100 billion, mostly through the Conservation Reserve Program for land retirement and through the Environmental Quality Incentives Program for adoption of conservation practices. The investments in advanced irrigation technologies have received US$ 10 billion subsidies under the Environmental Quality Incentives Program. Classen and Ribaudo (2016) identify several problems in conservation programs: the cost-efficiency of programs, the complexity of the agriculture-environment interaction, and the voluntary nature of conservation programs. They indicate that large gains in costs-effectiveness could be obtained using better information on producers' willingness to adopt conservation practices, and better knowledge on the relationships between conservation practices and ecosystem services.

5.3. Main proposals to improve water management

The main water management proposals to address water scarcity focus on improving the administration of water rights, introducing environmental flows in the management of basins, and developing water trading (Gray et al. 2015). The administration of water rights should include permits for both appropriation and riparian surface water, and groundwater permits have to be issued and quantified. Information on water abstractions has to be enhanced for both surface and groundwater, based on field metering and land use remote sensing. Environmental flows have to be established in watersheds by setting minimum stream flows or by issuing rights for environmental water. Water markets have a large potential to improve welfare, and water trading could be enhanced by simplifying trade rules and regulations while taking into account third party effects, especially environmental impacts. As the case of Australia shows, the problem for developing water markets is not the level of water prices paid by farmers before water trading, but rather the overhaul of the institutional setting based on an adequate water rights system and the measurement and control of water diversions.

For agricultural nonpoint pollution, the cost efficiency of abatement polices could be enhanced by concentrating efforts in the more polluting areas, making voluntary participation compulsory in critical areas, linking public payments to pollution abatement levels, and encouraging the stewardship values based on community conservation by groups of farmers.

5.4. Assessment of reform implementation in agriculture

In the United States, the water institutions are based in the appropriation or riparian water rights and institutional arrangements such as water compacts agreements for water allocation in interstate rivers. There are no basin authorities for the management of basins because states control the water in their territories and there is no federal authority for interstate basins.

In the 1970s, the former policies subsidizing the development of large water supply projects changed towards higher recovery costs. The main water policy initiatives have addressed water quality through the Clean Water Act of 1972 and the Safe Drinking Water Act of 1974, with public funding of US$ 90 billion in treatment plants and US$ 15 billion in drinking water systems. However, the aging urban water infrastructures require substantial investments. Irrigation is located in western and central plains states, with excessive water abstractions that have resulted in the fall of stream flows and groundwater tables. The water allocation system does not consider environmental flows, that can only be protected through the Endangered Species Act. During droughts, this approach leads to intense conflicts between farmers, environmental groups and public water authorities.

Water scarcity was addressed by the Reclamation Reform Acts of 1982 and 1992, which increased the costs of irrigation water by lowering subsidies. States and local agencies increased also costs recovery. These higher irrigation costs have contributed to stabilize the irrigation abstractions since the 1980s.

Water markets spur considerable interest in western states although water trading is only a small fraction of water use (around 4% in California). There are also several state water banks dedicated to the protection of environmental flows. Water markets are not developing because of the institutional setting, the opposition of interest groups in water exporting areas, and environmental concerns. The current institutional impediments to water trading are transaction costs that include legitimate protection of the environment and other third party effects, but also other components that could be reduced.

Better water management requires the overhaul of water rights with well-defined permits for all surface and groundwater abstractions, the issuance of water permits for environmental flows, and the measurement and control of surface diversions and groundwater extractions. These changes in in the institutional setting are also needed for the development of water markets, clarifying the current appropriative, riparian, and senior pre-1914 water rights, including groundwater rights, and unbundling water rights from land.

Agricultural nonpoint pollution is impairing a considerable number of water bodies. The very large public funding for nonpoint pollution abatement close to US$ 100 billion is not delivering substantial improvements of water quality in basins. Agricultural nonpoint pollution is a wicked challenge because of the complexity of the physical environment and the difficulties involved in the economic and ecological evaluation of abatement measures. Despite these obstacles, the cost-efficiency of measures could be enhanced by targeting disproportionate polluting areas delivering large environmental gains, and using a mix of incentives including not only taxes, subsidies, liability rules and compliance rewards, but also compulsory participation in programs, command and control approaches, and stewardship approaches by groups of farmers.

6. Conclusions

6.1. Cross-country evaluation of water reforms in agriculture

The water reform in Australia was prompted by the escalating water abstractions in the Murray-Darling basin between 1960 and 1990, creating severe water scarcity and environmental degradation. The water reform approach has been based on the establishment of water markets. The support of key stakeholders has been gained through the commitment of very large public funds, amounting to around AU$ 20 billion. These funds are being distributed between payments to states, investments in irrigation technologies, and buying water for the environment.

The water reforms in the European Union have been directed towards improving water quality in basins and the ecological status of water bodies. Water reforms in the 1990s focused in curbing point pollution with large investments in urban wastewater treatment plants, and efforts to reduce nonpoint pollution from agriculture. In the 2000s the water reform objective was expanded towards achieving good ecological status for all water bodies. Water planning was established for every European river basin, with programs of measures where water pricing is considered the key instrument.

In Israel, there was a command and control regime for water management. The first water reform was prompted by the growing water abstractions that were pressuring the scarce water resources in the country. The water reform consisted in investments in irrigation technologies and urban wastewater treatment plants, but these investments failed to curtail the growing abstractions and water resources depletion became critical during droughts in the 1990s. A new water reform was undertaken based on full cost water pricing, substitution of fresh water for recycled water in irrigation, privatization of water supplying and wastewater treatment companies, and large investments in seawater desalination.

In the United States, the water policies of subsidizing large water development projects were abandoned in the 1970s moving towards higher cost recovery. The water reform in the 1970s concentrated in improving water quality through large public investment in wastewater treatment plants and in drinking water systems, although substantial investments are required at present for the aging urban infrastructures. Irrigation contributes to excessive water abstractions in western and central plains regions, resulting in the fall of water streams and groundwater tables. This water scarcity was addressed in the 1980s by the reform of federal, state and local water agencies that increased the costs of irrigation by lowering subsidies, and these higher costs have contributed to stabilize irrigation abstractions since the mid-1980s. There has been interest in developing water markets, although water trading is at present only a small fraction of water use. An important program to abate agricultural nonpoint pollution was established in the 1990s with very large public funding, but the program is not delivering substantial improvements of water quality in basins.

In all these countries the former policy of subsidizing massive development projects to augment water supply have been mostly discontinued since the 1970s. In the case of Israel, the present large program of seawater desalination is being implemented by private companies which are recovering full financial costs from users. The energy and environmental costs of desalination could be reduced with appropriate technologies in the design of desalination plants, such as using renewable energy sources and diffuser systems for brine dispersal.

The first substantial water reform policies undertaken in the US, Israel and the EU in the 1980s and 1990s involved the abatement of point pollution, with considerable investments in urban wastewater treatment supported with public funding. The more extensive water reforms in agriculture are those of Israel and Australia since the 1990s, motivated by the unsustainable growth of irrigation abstractions in both countries. The severe water scarcity became critical during drought periods, and resulted in the overhaul of water institutions and management regimes.

A combination of command and control and economic instruments has been used in Israel to solve the acute water scarcity problem: reduction of water allocated to agriculture, reuse of treated urban wastewater in irrigation, water pricing, privatization of water companies in charge of water distribution and wastewater treatment, and investments in massive seawater desalination. The command and control regime of water in the agricultural sector has made possible the water reform by lowering the financial and political costs of reducing total water use in irrigation, substituting freshwater in irrigation for recycled water, and reallocating freshwater to other sectors.

In Australia the choice has been the establishment of water markets to address water scarcity. The institutional setting of water rights changed, coupled with the measurement and control of water diversions, in order to enable water trading. The support of farmers groups has been gained by multibillion investments financed with public funds in advanced irrigation technologies, and by private profits accruing to farmers from water trading. Large incentive payments to states have facilitated transferring the control of water from states to the federal basin authority. Additional public funds have been used to buy back water for the rivers in the basin. This type of approach is quite expensive for public administrations and would be beyond the means available for less wealthy countries.

In the US and the EU, the water scarcity situation is much less severe and affects only the western and central plains regions in the US and the southern regions in the EU. Water reforms in agriculture are focused on agricultural nonpoint pollution, which is a widespread problem across all regions in the US and the EU. Large public funds are being committed in the US for pollution abatement through conservation programs in agriculture, but there is no clear general improvement of water quality in basins. In the EU, the efforts to reduce agricultural nonpoint pollution are based on legislation without the support of specific public funds' incentives, but rather penalizing the farmers' payments from the European agricultural policy.[7] This European legislation has not resulted in significant reductions of agricultural pollution loads in most European water basins.

In both the US and the EU, there is interest in dealing with water scarcity by undertaking water reforms in agriculture. The instruments being considered are water markets in the US and water pricing in the EU. In the US, there is at present some water trading but it represents only a small fraction of water use, and several states have established water banks dealing with quite small trading volumes to support environmental flows. Potential gains from water trading could be in the range of billions of dollars per year during droughts, but the development of water markets involves overcoming significant barriers such as the institutional setting, the groups of interest in water exporting watersheds, and environmental concerns. Some of the main requirements include the overhaul of the water rights with well-defined permits for all surface and groundwater abstractions, unbundling water rights from land, measurement and control of water abstractions, and establishing water permits for environmental flows. Such water reform would be facilitated by critical water scarcity situations, as in the case of Israel and Australia, or by incentives provided by public funding to gain the support of key groups of interest.

[7] This follows the polluter pays principle enshrined in European water legislation.

In the EU, the instrument promoted by current legislation and the European administration is water pricing in irrigation, which is used for water allocation in urban water networks. The water pricing approach in agriculture faces important difficulties. One requirement would be to convert irrigation water from common pool resource managed by water user associations to a private good. Another difficulty derives from the very low price-elasticity of irrigation demand in the short run, where small reductions of irrigation would entail large price increases resulting in substantial farmers' income losses. Prices to balance supply and demand during droughts are so high that become politically unfeasible. Water markets are much more feasible, because farmers maintain income selling water rather than sustaining losses from large price hikes (Cornish et al. 2004). Also the advantage of water markets over water pricing is the efficient allocations from markets, while miscalculated water prices lead to welfare losses. In the long-run, a possible objective of water pricing in irrigation would be the recovery of the financial costs of provision. After achieving that, water pricing could be targeted towards charging for opportunity costs (resource costs in European WFD jargon) and for environmental costs.

The current reallocation mechanisms in southern Europe are informal water trading among farmers, transfers based in the urban priority of use during droughts, and transfers by institutional decisions of water authorities. There is evidence showing that these mechanisms achieve a reasonable efficient allocation in some basins (Albiac et al. 2016). This current system could be more feasible than the Australian model of water markets.

6.2. Challenges and solutions for improving water reforms in agriculture

Water reforms are needed in many river basins around the world facing water scarcity from excessive water abstractions and deteriorating water quality from large pollution loads. Water scarcity is common in arid and semiarid regions with substantial irrigated agriculture, resulting in mounting competition among human uses and considerable environmental damages. Water quality degradation is driven by pollution coming from human activities and affects basins in all regions.

Because irrigation represents the major share of global water abstractions (70%, WWAP 2016) which drive the growing water scarcity in arid and semiarid regions, water reforms in agriculture are crucial to advance the sustainable management of water in basins.

The challenges for successful water reforms in agriculture are the sound design of the water reform, and the support of the key groups of stakeholders. Water reforms should be based on rigorous analysis based on economic and biophysical information, that could support the appropriate measures and instruments for reform. Water reforms change the power and benefits of the groups of stakeholders, so the active support of the groups gaining with the reform is needed, while the losing groups have to be compensated to avoid the failure of the reform.

Water reforms in agriculture are needed in basins under acute water scarcity, and the solutions involve curbing irrigation abstractions and reallocating water to urban, industrial and environmental uses. Therefore the viability of reforms requires compensating farmers for the reallocation of water from agriculture to other sectors. The water reform in Australia shows that compensations to agriculture have been substantial, through public investments in irrigation technologies and farmers' gains form water trading. In Israel, the command and control system for water in agriculture has facilitated reallocation to other sectors, and there has been compensations by maintaining lower water prices for irrigation and by providing farmers with cheap recycled water. Without command and control, the political difficulties and costs of water reform in Israel would have been much higher under a system based on private water rights.

The water reform in agriculture has been much more limited in the US and the EU because water scarcity is less severe and affects only some regions. The reform has entailed the reduction of subsidies for irrigation in existing or new water projects, which has contributed to the stabilization of irrigation abstractions. However, water scarcity in stressed basins has not been solved because abstractions remain high. There have been compensations to farmers in both the US and the EU through public funding for investments in irrigation technologies.

Investments in irrigation technologies to solve the growing water scarcity in basins across the world have been advocated among policy makers in international meetings and by international organizations, although recently some international organizations are calling for institutional investments that could enhance the coordination and cooperation of stakeholders in addressing water scarcity. Pure irrigation efficiency gains at plot or district levels lead to lower flows in basin, as demonstrated by the multibillion investments in irrigation technologies undertaken in Australia and Spain. The solution is that water authorities have to reduce water allocations in modernizing irrigation districts to avoid the fall of basin stream flows, although farmers will oppose such reduction in allocations.

As indicated above, water markets seem a better solution than water pricing in irrigation to address water reallocation in stressed basins. The problems with water pricing derive from the price inelasticity of irrigation demand resulting in large income losses to farmers, the possible miscalculation of water pricing leading to welfare losses, and the fact that irrigation water is mostly a common pool resource difficult to tax (e.g. groundwater). Some countries could not have the choice of instruments because of the path dependency of policies, but rather to enhance the process of current reforms where instruments are already decided.

Water reforms based on establishing water markets require quite demanding tasks, as shown by the Australian and the US experiences, and could involve very large funding commitments to gain the support of private and public stakeholders. The administrative and technical requirements are also strong involving the overhaul of current water institutions, the issuance of permits for all surface and groundwater abstractions and for environmental flows, and the measurement and control of all abstractions. Water markets should be based on water consumption rather than on water diversions in order to avoid the fall in basin stream flows,[8] although trading water consumption would increase the transaction costs and reduce the potential gains from trading.

Water reforms should also address agricultural nonpoint pollution, and the experiences in the US and Europe show the difficulties involved in nonpoint pollution abatement. Both penalizing the CAP subsidies of farmers in the EU or large conservation payments to farmers in the US, are not delivering an improvement of water quality in basins. One positive development has been the reduction in polluting emissions from the modernization of irrigation technologies taking place in all countries reviewed. However, pollution remains and better abatement results require a combination of incentives including not only the current subsidies or penalties, but also command and control with compulsory participation, and collective action approaches based on cooperation among farmers.

The combination of policy measures such as command and control, economic and institutional instruments, should be selected to solve the specific water problems in each region while accommodating the stakeholders' interests. However, any successful water reform involves some degree of stakeholders' cooperation within the suitable institutional setting. The policy design of the water reform should also take into account the path dependency of previous water policies and institutions.

Finally, water reforms in agriculture should consider the possible contribution of investments in new technologies for the provision of water such as wastewater recycling, seawater desalination, capture of excess runoff for groundwater recharge, and reuse of urban storm water.

[8] Trading water to more efficient irrigation areas increases evapotranspiration

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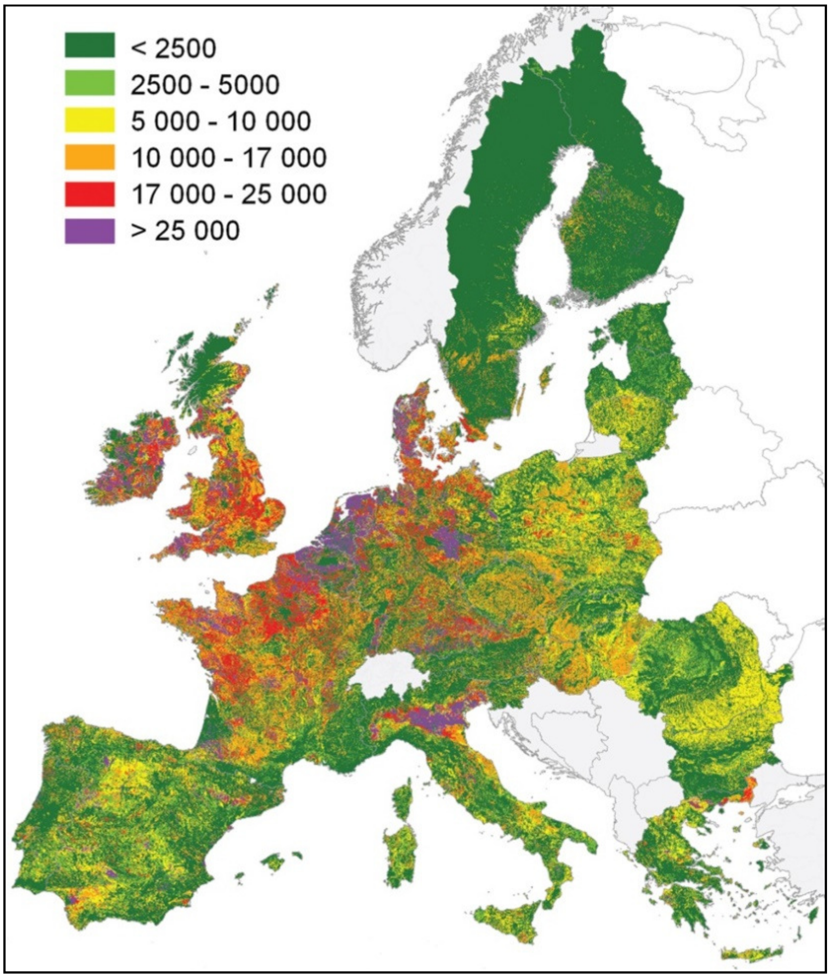
Appendix

Figure 1. Density of the nitrogen inputs in European soils (kgN/km^2).



Source: Leip et al. (2011).