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Adaptation of irrigated agriculture to adversity and variability under conditions of drought and likely climate change: Interaction between water institutions and social norms

Ariel Dinar* and Uday Kumar Jammalamadaka

Water Science and Policy Center, Department of Environmental Sciences, University of California, Riverside
E-mail: adinar@ucr.edu

Agriculture is an important source of welfare in many developed and developing countries. It is also the most vulnerable to climate change of all the other sectors in any economy. The adaptation literature demonstrates how concerted adaptation strategies can minimize the resulting negative impacts on rural households. Adaptation may include modification of existing or developing new institutions and infrastructures to support the necessary adaptation options and strategies. Institutions can be developed by the state or by the community. The community faces a set of social norms under which it operates, that interact with new institutions and affects it adaptability to changing conditions. This paper addresses the role of official institutions and local social norms in adaptation of irrigated agriculture to adversity from changes in climatic conditions. A simple analytical framework is developed to demonstrate the effectiveness of several institutions along with the existing social norms and infrastructure, using conditions of drought and flood, as representative cases of climate change. Evidence from exiting studies is used to assess the role of institutions, social norms, and infrastructures in supporting various adaptation strategies, including developing and adopting different agriculture and water management technologies and other related adaptation strategies.

1. Introduction

In their recent book, "Why Nations Fail" Acemoglu and Robinson (2012) argue that nations are poor not because of their geographical location, culture, or inability of their rulers to select policies that will make them rich. To understand world inequality one has to understand the social structure. "…how different types of policies and social arrangements affect economic incentives and behavior" Acemoglu and Robinson (2012: 69). A decade earlier, David Mosse (2003) observed in two neighboring villages in the same watershed in south India the contrasting levels of collective action across them. It was the underlying cultural ecologic institutional differences, not the geography nor the ecological conditions, that led to differences in prosperity between the 'red-soil

*Corresponding author.

village' and the 'black-soil village'. These two works highlight the role of institutions and their fragility in sustaining societal prosperity at various levels.

1.1. Institutions, norms and infrastructure

Institutions do not perform in a vacuum. They interact with existing social norms in the society and are supported by the infrastructure that a society is endowed with. Crawford and Ostrom (1995) suggest that norms are a subcategory of institutions. We first clarify the differences between institutions and norms (Schlüter & Theesfeld, 2010). While the term "institution" dates back at least to 1725, there is still no agreement today on it's definition today (Hodgson, 2006). By North "Institutions are the rules of the game in a society, . . .the humanly devised constraints that shape human interactions. Institutions reduce uncertainty by providing a structure to everyday life." (North, 1990: 3). Ostrom defines institutions as "the prescriptions that humans use to organize all forms of repetitive and structured interactions including those within families, neighborhoods, markets, firms, sports leagues, churches, private associations, and governments at all scales. Individuals interacting within rule-structured situations face choices regarding the actions and strategies they take, leading to consequences for themselves and for others." (Ostrom, 2005: 3) Both North and Ostrom's definitions of institution are operationally the same and are adopted in this paper.

In moving now to define social norms we rely on Schluter and Theesfeld (2010) and Durlauf and Blume (2008). According to Schluter and Theesfeld (2010), norms are standards of behavior that are shared by the members of a social group. They can be internalized and adopted by the individuals, or they may be externally enforced by positive or negative sanctions by the group. There are additional very relevant definitions used. Durlauf and Blume (2008) define social norms as customary rules of behavior that coordinate individuals' interactions. Bicchieri (2006) like Crawford and Ostrom (1995) indicates that social norms are supported by informal sanctions (or not at all) by the group and they are driven by the expectation of compliance by other individuals' actions and beliefs in the group. Even when there is no evidence of norms being complied with, they still may be affecting the behavior of individuals. Bicchieri distinguishes between institutions and norms: institutions may be the rules of the game, determining the type of players that interact in that game. But social norms are the rules which govern the behavior of the players and lead them to different equilibria in that game.

The last component in the societal setup is infrastructure. Saleth et al. (2011) define water infrastructure to include components such as storage systems, distribution networks, flood protection mechanisms, water harvesting structures and water infiltration points. Infrastructure has been found to be closely associated with institutions, especially in the water sector (Fung, 1998). Matthew et al. (2011) argue that equally important with infrastructure design is the need to create institutional structure capable of integrating various measurements mechanisms into flexible infrastructure operations.

It is obvious that different infrastructures necessitate different set's of institutions. For example, institutions that have been designed to allocate water from a canal will not perform as well when the water storage/delivery infrastructure is a joint well. Bardhan (2000) and Hess (1999) present examples of Common Pool Resources (CPR) where the interactions of social Norms, institutions and infrastructure, with minor variations, lead to different outcomes in each case. For example, in the Tamil Nadu region of India, water systems managed by Public Works Department of the government are inefficient due to rent seeking behavior and violation of rules. These water systems (unlike user managed CPRs) also frequently suffer from poor maintenance of infrastructure as the norms of system maintenance by downstream users are not present (Bardhan, 2000). In the analysis below we assume that the infrastructure is given.

1.2. Institutions and social norms interactions

The role of institutions and social norms becomes more critical as societies face harsher situations, such as in the case of climate change that translates into water supply variability with floods and droughts becoming more frequent, prolonged, and extreme (IPCC, 2007). A recent study on adaptation to climate change recommends to: "Invest in human capital, develop competent and flexible institutions, focus on weather resilience and adaptive capacity..." (World Bank, 2010a: 71). Several other works identified the important role of social norms influencing the effectiveness of local institutions in coping with natural resource scarcity. For example, "gender sensitive analysis is important to ensure women's participation in long term climate change adaptation strategies, which might have been constrained due to their traditional social norms in Bangladesh" (Khan et al., 2010: 2). Rustagi, Engel, and Kosfeld (2010) studied the norm of limited (sustainable) resource exploitation among the Oromo People (in Bale, Ethiopia), collecting firewood from the forest. They find that each individual in a community has a different utility value for the social norm, and communities with more individuals who significantly value the norm (conditional cooperators) invested more time and resources in monitoring resource use. This resulted in more productive forests (a common pool resource-CPR). Fishing communities also have been observed to have strict norms of sustainable resource use. In Japan and Solomon Islands the fishing communities have been observed to punish over exploitation of fisheries by social boycott in all other spheres of economic and social activities (McKean, 1992; Hviding & Baines, 1994). Agrawal (n.d.) contends that climate change will have a more significant impact on weak social groups, and that the local institutions (at the community level) allow these social groups to use assets and resources in adapting to it. Agrawal (n.d.: 3) indicates that institutions influence adaptation and climate vulnerability in three critical ways: first, they shape the impacts and the vulnerability to climate change effects; second, institutions act as a go-between individual and collective responses to climate impacts and thus shape the community and individual outcomes of adaptation; and finally they act as the means of delivery of external resources to facilitate adaptation, and thus govern access to such resources. Hence, social norms may enhance or reduce the ability of communities to cope with adverse climatic changes through the interaction with local institutions.

Given their limited resources and time governments have to prepare for the effects of climate change; it is important that they use both very efficiently. Governments and bureaucracies have a tendency to be path dependent, i.e. they tend to perpetuate the status quo even if the system is inefficient. This is associated with a large social cost in terms of the delay in adapting to the trend of rising global temperatures, stochastic weather fluctuations, decreased availability of water, and other effects of climate change. More often the changes governments introduce have exacerbated the problems. The Nepal Irrigation Institutions and Systems (NIIS) database collected by the Workshop in Political Theory and Policy Analysis at Indiana University (Shivakoti & Ostrom, 2002) provides testimony to the inefficiency government investments/interventions can introduce into an existing resource system. They find that the rent seeking behavior and existing system rules in the government lead to not only prohibitive costs but also to destroying existing efficient irrigation systems. They find that only half of the Agency Managed Irrigation Systems (AMIS) in Nepal are able to deliver water to the tail end users even in the monsoon season, and only one tenth are able to do so in water scarce periods. Whereas 90% of Farmer Managed Irrigation Systems (FMIS) are able to provide water to tail end users during monsoon and 25% in water scarce periods. The FMIS require minimal investment and are more efficient, but the government is unable to duplicate their success due to a lack of understanding of local water institutions and social norms.

The literature on role of institutions in managing natural resources has viewed institutional change as a process where the institution adjusts itself to social, economic, political, and physical conditions. This literature attempts to study what factors cause socio-economic systems to collapse in some cases and persist despite adverse circumstances in other cases. While the collapse of socio-economic systems is easily explained by the exploitation of resources by 'rational economic agents,' the sustainable use of common resource systems on the other hand confounds the belief of self-interested economic behavior. The institutional framework literature assumes social norms are embedded in the institutional framework (Hotimsky, Cobb, & Bond, 2006) which Poirier and Loë (2010) point out, assumes away the effect social norms have in the transmission of external interventions through the system.

The extensive literature (Cordell & McKean, 1992; Somanathan, 1991; Ostrom, 2002; Acheson, 1993) on existing common resources attributes this to the presence of path dependent institutions and social norms, which regulate the self-interest behavior of the agents involved. The social institutions commit to monitoring and sanctioning norm-violating behavior. This literature also observes that 'common resource' systems collapse when the existing institutions cannot regulate the socio-economic behavior of agents any longer, due to the lack of sanctions or monitoring behavior. Bardhan (2000) observes that in government managed CPRs, with a large number of community members confirming to observe the social norms, the community cooperates in violation of the 'inflexible' government rules but also ensures the maintenance of field channels and other infrastructure. Bardhan finds that maintenance of CPRs and cooperation in system use is positively dependent on perceived equity, social homogeneity, monitoring of resource and water scarcity.

Most theoretical works on social norms apply game theory to explain the sustainable use of common resources (Fehr & Schmidt, 1999; Sethi & Somanathan, 1996; Bowles, 1998). The theoretical literature on role of social norms in sustainable CPR use can be broadly divided into three categories: (1) Role of benefits from adherence and sanctions for violation of norm; (2) Role of Self-Sacrificing Agents; and (3) Role of differences in the source of scarcity

Role of benefits from adherence and sanctions for violation of norm. Sethi and Somanathan (1996), Oses-Eraso and Viladrich-Grau (2007), Noailly et al. (2005) etc. analyzed the effects of benefits for adherence and sanctions for violation of norms on agent behavior in the evolutionary game theory setting. This strand of the literature largely ignored the effects of stochastic resource supply (by assuming a fixed resource supply) and also feedback effects of current decisions on future behavior (with the exception of Noailly, Withagen, & van den Bergh Jeroen, 2007). Sethi and Somanathan (1996) find that equilibrium is possible only when homogeneous strategies are implemented by all agents. Oses-Eraso and Viladrich-Grau (2007) build on this by accounting for the importance of the proportion of norm-followers in the population. They find that equilibrium is possible even with heterogeneity in agents' strategies as long as the critical population of norm conformists exists. Noailly et al. (2005) add to this by introducing enforcers and monitor their neighbors in the framework. They find that with feedback effects and monitoring, a resource sustaining equilibrium is possible with a critical number of enforcers in the population, despite a stochastic environment.

Role of Self-Sacrificing Agents. Ostrom (2000) describes the role of 'Willing Punishers' tested in experiments in Switzerland and Japan (Fehr & Gachter, 2000) as critical in initial rounds of a game to ensure that agents with little trust also contribute to public goods. But, this sanctioning behavior may impose transaction costs for monitoring and punishing on the 'Willing Punishers' themselves. Sethi and Somanathan (2003, 2004) analyze the importance of such punishers for cooperative equilibrium to exist and find that the presence of such 'reciprocator' agents would lead to cooperative equilibrium only within a range of transaction costs and returns to resource use. Heterogeneity of the ability to sanction or to punish may also interact with this range to limit the effect sanctions have on cooperation. Oses-Eraso and Viladrich-Grau (2011) modify the role of enforcers to benevolent agents bestowing resources on other agents to ensure the sustainable use of a CPR. The presence of such patrons significantly reduces the extraction by members with a strategy for high resource-exploitation, also increasing the chances of CPR sustainability.

Role of differences in the source of scarcity. Oses-Eraso, Udina, and Viladrich-Grau (2008) introduced a new direction of research in CPR use and differential agent exploitation based on source of scarcity. They find that in general a concern for resource scarcity affects agents extraction of the resource; but may not prevent resource depletion due to feedback effects from current usage on future exploitation levels. They conclude that societies with large initial stocks will demonstrate limited willingness to reduce exploitation of resource whereas societies with initial scarcity are more sensitive to resource availability in their resource use. Given the same levels of scarcity; societies with higher resource exploitation, leading to human-induced scarcity, tend to exploit the resource more due to feedback effects in future periods. They thus distinguish between agent behaviors in response to existing environmental scarcity and human-induced scarcity, which may strengthen or counteract each other.

Indeed, the works presented in the short literature review on role of institutions and role of social norms in social decisions supports what Hess (1999) suggested, namely that institutions may be indeed the rules of the game, but social norms are the rules which govern the behavior of the players and lead them to different equilibria in that game.

In this paper we focus on the role of social norms and the interaction between infrastructure, institutions and social norms in adaptation of irrigated agriculture to adversity and variability under conditions of drought and floods, which are likely derivatives of climate change. The question that this paper aims to answer is whether or not there is evidence of a relationship between social norms and institutions (local or national) that could explain level of success in responding to water extremes across regions. We start by developing a conceptual framework that will be utilized in the remaining parts of the paper for interpreting examples and anecdotal information to make our point, namely, that it is the social norms and the institutions they interact with, which allow different societies cope with adversities of water supply with given set of infrastructure. We demonstrate, using anecdotal information how irrigated agriculture can be strengthened for resiliency and sustainability in facing future climate change.

2. A simple analytical framework

Assume a negative relationship between welfare and level of water scarcity for a given level of institutional performance and under an existing infrastructure. This means that as water becomes scarcer, welfare is reduced per a given level of institutional performance. For simplicity assume that the marginal reduction in welfare increases as resource scarcity level increases. Assume two levels of institutional performance, high and low. Based on Saleth and Dinar (2004) we can claim that the welfare reduction line with low performing institutions will be strictly below that of the high performing institutions (as can be seen in Figure 1). For communities with high-level functioning institutions that are able to address resource adversity better than communities with low-level func-

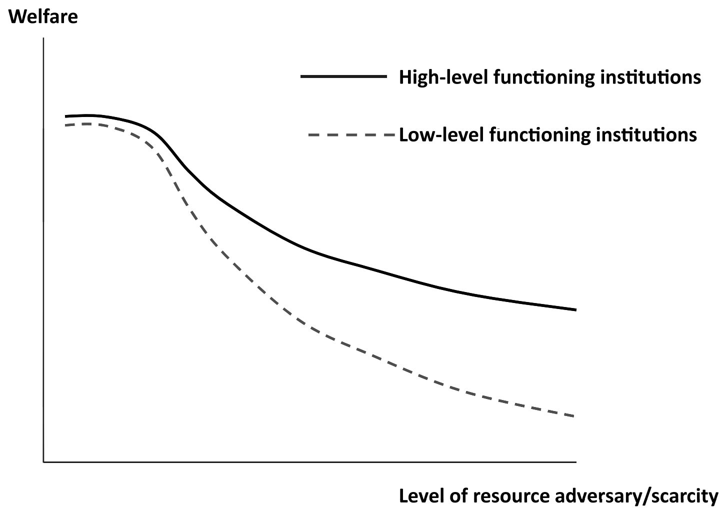

Figure 1. Relationship between level of welfare and level of resource adversity for high and low levels of institutional performance.

tioning institutions the marginal decrease in welfare will be smaller as level of scarcity increases. At low level of resource adversity/scarcity there is no significant difference in welfare between high and low-level performing institutions.

Further, let us introduce another relation that includes also the effect of social norms on the level of institutional performance and thus on economic performance and welfare. The rational for this relationship has been established in the literature (Ostrom, 2010: 160–163; Ostrom, 2008; Cialdini, 2007) and was recently empirically tested in Meek at al. (2010: Hypotheses 2b and 3b). Figure 2 presents the relationship between level of institutional conduciveness of a norm and the level of the institutional performance. We assume a non-increasing level of institutional performance as a function of the level of conduciveness of the social norm.

Our thesis in the following sections is that existing institutions have a positive effect on the level of welfare under given adversity conditions in communities (or states) with higher levels of institutional conducive social norms, and vice versa. We demonstrate in the following section, using examples from the literature how social norms may enhance or impede institutional adaptation to water scarcity through adaptive capacity improvement measures of various types.

3. Climate change and irrigated agriculture

The literature provides up-to-date information on impacts of climate change on irrigated agriculture. Published studies suggest that well-functioning institutions may not prevent the impact of climate change on agriculture, but certainly they may reduce the

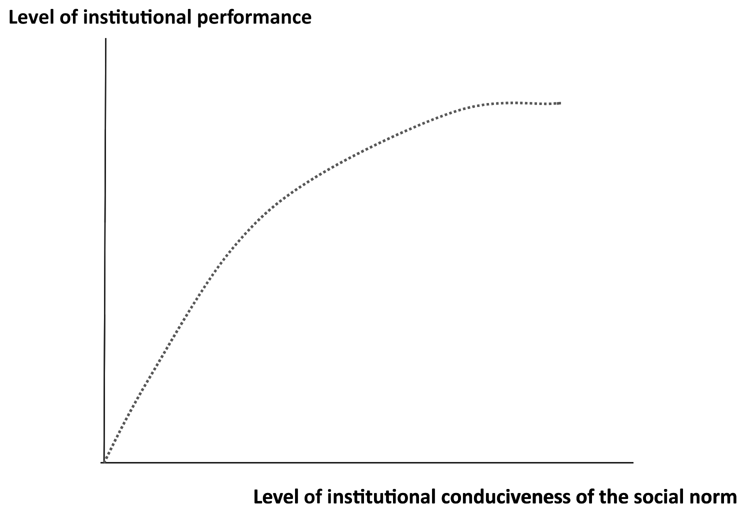

Figure 2. Relationship between level of institutional conduciveness of a social norm and level of the institutional performance.

impact (Dinar et al., 2008; Mendelsohn & Dinar, 2009; Dinar & Mendelsohn, 2011). Saleth et al. (2011) identified several pathways for the irrigated sector to adapt to climate change, using drought as an attribute of climate change. We use Saleth et al. (2011) set of adaptation measures to address drought impacts. We also use several examples from the literature to demonstrate role of institutions in addressing flood impacts and adaptation. Adaptation to flood in agriculture is less documented in the literature then adaptation to drought. Also, it is hard to separate the agricultural sector from the rural/semi urban sectors. Several studies that address flood impact and adaptation estimate that disasters from flood range between 35–50 percent of all disasters between 1970–2010. Highest shares are in Africa and South Asia (50 and 45 percent respectively). However, no indication on how much is in rural areas or in the agricultural sectors (World Bank, 2010b). However, the study reported by the World Bank recommends that "…governments must provide adequate infrastructure and other public services…" (p. 6) and also that "…good institutions must develop…" (p. 8). Although foods are an important aspect of climate change impact and adaptation, we will focus in this paper mainly on drought.

In order to address the impacts of drought, farmers have been using several adaptation options such as the use of science and technology, reliance on adaptive farm management practices, modification in water infrastructures, and changes in water institutions at community or regional levels (Saleth et al., 2011). As we evaluate these adaptation options, which are currently present in managing agricultural impacts of droughts in various contexts, we can learn a great deal about farmers' likely response to possible events of climate change. We provide evidences on the role of institutions in the four adaptation mechanisms that were mentioned above, as well as the critical role of social norms and their interactions with existing institutions in the particular context of managing the agricultural impacts of droughts.

Drought affects agricultural production by eliminating or reducing water availability, either directly by rainfall failures and reduced water supply, or indirectly by increasing temperatures that lead to higher evapotranspiration rates, or both. Such water scarce situations affect both crop and livestock production, leading to reduced farm income. Floods affect agricultural production by eliminating the crops on the flooded fields or preventing the crop from growing by creating aeration problems in soaked soils. Various technological options for adapting the crop and irrigation systems are available to farmers, depending on their crop types, farm sizes and irrigation infrastructure conditions. In this section we provide examples to illustrate how farmers currently utilize various adaptation methods to address impacts of droughts (or floods) on agriculture in their communities, and how such adaptation methods can or should be introduced so that they effectively encounter future likely impacts of climate change. While water and irrigation-related scientific and technological improvements play a direct role, water institutions play an indirect but critical role in providing the economic incentives and organizational basis for the adoption of existing technologies as well as the development of new technologies and scientific advancements. However, all adaptation options could not function properly without supporting infrastructure, institutions, and norms that will support their adoption and appropriate performance. Properly designed and functioning infrastructure is more critical for adequate adaptation to floods, but it is important as well for addressing droughts.

3.1. Public provision of science and technology solutions

Use of drought or flood resistant crop varieties is an important example that demonstrates how farmers can introduce technological innovation to adapt their production practices to lower levels of water supply and at the same time increase water use efficiency and productivity, or sustain flooding of their fields. One example of such technological innovation is the drought resistant soybean varieties that have been developed in north-east Brazil, using public/government funding (Oya et al., 2004). Another example is the flood resistant "Scuba" rice (IRRI, 2009).[1] The Scuba variety that was genetically modified to survive long periods under water is being adopted by many farmers in south Asia. Research on drought resistance of various crops (e.g., wheat, sorghum, soybean) on the other hand allows keeping plant functions at low water status and the recovery of plant water status and plant function after stress. Bioengineering research in China has shown that the s-Dwarf wheat variety possesses all these traits and displays an ability

[1]This is the only example of adaptation capacity provision we introduce for the case of flood. We use this example because it demonstrate a well-functioning system of public funding, distribution and adoption institutions, and social norms that ease the switch from the conventional to the flood resistant variety.

to both survive and recover from drought in high rates when compared to other varieties under severe water scarcity (Zhang et al., 2005). Similarly in the rain-less region of Northern Sudan, the drought tolerant sorghum hybrids Hageen Dura-1 and NAD-1 have increased the yield 1.5 times and 4–5 times compared to the traditional sorghum cultivars (Ejeta, 2009). The use of these technologies necessitates the support of proper institutions, such as agricultural extension, supply of the new seeds, and of course the acceptance of the genetically modified seeds by the farmers.

3.2. Adaptive management strategies either imported or endogenous

On-farm crop and irrigation management practices could, to some extent, substitute technology in order to increase water productivity and can be introduced, using a variety of approaches. Saleth et al. (2011) list a partial list of several management practices, including precision agriculture (Bongiovanni & Lowenberg-Deboer, 2004), tillage method conversion (Unger et al., 1991), contingency crop planning (Wilhite, 2000b), irrigation scheduling (Pereira, 1999), wastewater reuse (Asano, Maeda & Takaki, 1996) and conjunctive use of surface and groundwater (Wrachien & Fasso, 2007). Another important adaptation strategy is the adjustment in the area cropped to the available water.[2]

For example, conservation tillage systems are associated with leaving a minimum of 30 percent of crop residue on the soil surface to reduce or eliminate water loss. Level of effectiveness depends on regional conditions (Moreno et al., 1997). Research demonstrated that in drought-prone Mediterranean climates the benefits of conservation tillage far outweighed those of conventional tillage practices. Moreno et al. (1997) showed that both water use efficiency and crop yields were higher under conservation tillage compared with conventional tillage methods.

Contingency crop planning is another management approach used to reduce the magnitude of the negative effects of droughts. It is a dynamic process that takes into consideration socioeconomic, agricultural, technological and institutional parameters (Wilhite, 1996). Successful plans should include (pre) assessment tools such as drought criteria or triggers (e.g., interim rainfall levels) to initiate changes in the crop growing process, and development of emergency response procedures (Shepherd, 1998; Wilhite et al., 2000). Various methods of contingency crop planning can be implemented, depending on the timing and duration of the water deficit during the growing season, and the existing institutions to support it. When a drought or water deficiency can be anticipated prior to planting, mixed or inter-cropping may increase the chances of crop survival. For example, Indian farmers plant a mix of staple food crops in anticipation of drought. This plan provides them with insurance against total crop failure. One aspect of this plan is the substitution of long duration high-yield crops with short duration low-yield crops with lower level of drought risk (Wilhite, 2000a). Crop thinning is another contingency plan that takes place if precipitation is delayed after sowing. Sastri (2000)

[2]We thank an anonymous reviewer for suggesting this important adaptation practice.

reports that the thinning of sorghum in every third row at the onset of drought increased yield almost two-fold. Similarly, Venkateswarulu (1992) searching for drought-affected sorghum reports that thinning increased crop yield up to four fold.

3.3. Irrigation practices and technological modifications

Irrigation modernization is one of the feasible technological options that farmers utilize to increase water use efficiency. Significant increases in crop yield and considerable decreases in irrigation water consumption have been observed when pressurized irrigation systems (sprinkler or drip) replace flood irrigation methods (e.g., Letey et al., 1990). This is the result of an enhanced irrigation uniformity and better control over depth of drainage (Playan & Mateos, 2006). Examples suggest that on-farm water use efficiency has improved up to 90 percent in the case of sprinkler systems observed in north-eastern Spain (Dechmi et al., 2003). Analysis of irrigation along the King Abdullah Canal in Jordan suggests similar results with greatest irrigation efficiency coming from pressurized systems, which have shown up to 30 per cent greater project efficiency over that of the traditional non-pressurized surface irrigation systems. The increase in water use efficiency in pressurized system is attributed to the reduction in losses due to evaporation, deep percolation and surface runoff (Battikhi & Abu-Hammad, 1994). However, institutional requirements and appropriate farm structure are a major prerequisite for successful adoption of the new irrigation technologies (Campbell & Dinar, 1993; Dinar, Campbell, & Zilberman, 1992).[3] To ensure that the conserved water either at the basin level or at the farm level is effective, proper institutions have to be in place. For example, at the basin or irrigation project course adequate water right system should be adjusted to the new hydrological balance so that the downstream users are not negatively affected from reduced return flows (Ward & Pulido-Velazquez, 2008). To address the 'expansion effect' regulations that return the conserved water to the watershed have to be developed (Dinar & Zilberman, 1991).

Water harvesting systems are examples of methods that increase water availability and water use efficiency in rainfed regions under water scarce conditions. For example rainfall cistern systems have been shown to decrease precipitation runoff (waste) by nearly 50 percent in the Chhattisgarh region of India and increase the productivity of soybean and rice by 63 and 76 per cent respectively (Wilhite, 2000b). "This system uses a series of alternating sunken and raised beds in which crops are planted based on their consumptive water needs. Highly consumptive crops such as cotton and maize are placed in the sunken beds whereas low consumptive crops are placed in the raised beds.

[3]Here we are indebted to an anonymous reviewer for bringing to our attention the caveat that adoption of water saving technologies at farm level may not result in water savings at the basin level (Ward & Pulido-Velazquez, 2008). Furthermore, adoption of water conserving technology may even result at the farm-level in use of more water, following the 'expansion effect' that is typical to situations where water is scarce but land is not limiting so all conserved water are used on land not previously irrigated (Dinar & Zilberman, 1991).

The excess rain from the raised beds automatically flows into the sunken beds, ensuring the water flow into the adjacent crop and thereby reducing the potential for surface runoff" (Saleth et al., 2011: 477–478). In the Uda Walawe area of Sri Lanka, concrete canal lining has increased available water for consumptive use by reducing canal seepage by 50 per cent, resulting in a significant expansion of irrigated land (Meijer et al., 2006). Similar results are observed in community projects that replace earth canal with brick-lined canals in tank-based irrigation supply systems in Tamil Nadu and Rajasthan, India (World Bank, 1998a: 41–42; World Bank, 1998b: 76–77). These technological improvements necessitate supporting social norms and local institutions. In particular in the replacement of seepage-improved canals, where norms in the form of individual in-kind labor contributions are an essential part of the joint investment, proper enforceable social norm and regulatory institutions are essential.

3.4. Water sector institutions

Irrigated agriculture competes with other water-consuming sectors on the same scarce water resources. Therefore, in the face of drought and climate change, increased water conservation and water productivity must not only be achieved within the agricultural sector, but also within the water sector as a whole through a change and adaptation in water institutions. The most important water institutions that we discuss in this section are a water market and an incentive-based water pricing schemes.

Moving water from low value to high value use, under scarce water condition could benefit all sectors involved and can be achieved by various means, including the implementation of incentive-based pricing schemes (Dinar & Saleth, 2005) or by establishment of a water trade institution (Easter, Rosegrant, & Dinar, 1999). Water supply augmentation can be achieved by integrating all water (surface, groundwater wastewater, brackish, etc. . . .) and increasing supply from water reuse and recycling. Priority is always assigned to meet basic needs such as municipal water uses (household uses) and allocating the remainder between lower priorities, such as industry and agriculture (de Assis de Souza Filho & Brown, 2009).

Water pricing schemes also aim to replicate the economically efficient allocation of water in a free-market system based on the willingness to pay of users. However, water pricing policies face many drawbacks associated with the composition of social norms (regarding the payment culture) and other supporting institutions and practical difficulties (Dinar & Subramanian, 1998). It also requires infrastructural modifications to enable volumetric water allocation to make the incentives effective. Pricing is ineffective intervention when uncertainties regarding the willingness to pay of water users exist, or when water supply fluctuate over time, introducing uncertainty to the planning of its delivery (de Assis de Souza Filho & Brown, 2009). Political economy associated with water pricing reforms is also inherent in the selection and implementation of appropriate water price policies (Dinar, 2000).

Water allocation via market is an economically efficient alternative both to pricing schemes and to the priority allocation systems which do not provide the necessary flexibility under drought conditions. Water markets can reallocate water not only within sectors but also across sectors, as well as on a temporary (spot or rental markets for water rights) or permanent basis (permanent transfer of water rights). Water markets allow the true value of water to be revealed, which gives incentives for the efficient use of the resource by various users (Dinar & Letey, 1991; Easter, Rosegrant, & Dinar, 1999). The irrigated agricultural sector benefits due to a potential for increased profitability from water conservation (from investing in water saving irrigation technologies). Similarly the urban sector benefits because of the increased availability of water for urban use. And the environmental sector benefits because of the decreased environmental pollution (deep percolation of pesticides in the return flow of the irrigation water), which could be reduced due to the increase in irrigation efficiency driven by technology and overall water management that water markets encourage (Dinar & Letey, 1991). There are also groundwater markets and water banks that have evolved in India, Pakistan and California (Dixon & Moore, 1993; Kolvalli & Chicoine, 1989; Meinzen-Dick, 1996). Water banks operating in California and Colorado in the US help to save surplus water in wet years and make is available in dry years.

Again, these two institutional mechanisms—water markets and pricing—that serve as adaptation measures, cannot stand on their own without support of infrastructure (to measure volume used, to transfer water from low value to high value use, etc. ...); support of additional institutions, such as legal framework to allocate water rights, proper use of proceeds from the collected water prices, and from norms by the users that allow proper functioning of the adaptation measures is needed.

3.5. Other institutions

The government can also introduce incentives for drought adaptation, which can take the form of subsidies (loans, rebates or grants). These incentives are used, for example, by farmers to introduce improved water saving irrigation technologies, which is a socially beneficial use of the subsidy as found in the case of water-scarce Israel (Dinar & Yaron, 1990, 1992).[4] Subsidies can also be provided for development and purchase of drought resistant crop varieties that have been introduced by public or private research centers, such as the announcement by the Government of Ghana about subsidization of the "Pioneer" seed, which is drought resistant (Ghana News Agency, 2012).

Prior to 1989 subsidies were the primary way by which Australia addressed drought impacts in the agricultural sector. Federal loans were granted for livestock carrying and re-stocking purposes where credit was not available through commercial sectors, and rebates of rail freight and other forms of travel assistance were also given to aid in the conveyance of fodder and water to drought-striken areas, as well as the conveyance of

[4]This statement has to be viewed under the caveat introduced in footnote 3.

livestock from the drought-affected areas to drought recovered regions (Botterill, 2003). However, Unabated subsidizing in Australia to reduce drought impacts under national disaster relief was counter-productive as the government was not able to enhance the sustainability of the agricultural and livestock sectors. Subsidies have also been provided in pre-1990 South Africa to assist in the maintenance of herds during water scarce periods (Wilhite, 2000a). Following 1990, South Africa and Australia adopted new policy measures that removed coverage of drought under national disaster relief arrangements and implemented various relief schemes that encouraged on-farm sustainability and conservation. In South Africa, drought relief was contingent upon adherence to stocking rate standards and other conditions of a conservation farm while in Australia aid was distributed to farms who demonstrated a long-term productive future in agriculture under the Farm Household Support Act (Botterill, 2003). The revisions in federal policy in both countries were effective in reducing drought hazards and impacts by reforming policies that once encouraged resource degradation and delayed the onset of impacts, into policies that encouraged sustainability and reduced the potential for negative drought impacts. In the case of Sub Saharan Africa, international aid has played a major role in direct and indirect drought relief interventions (Dinar & Keck, 2000).

Another intervention governments use to address the risks associated with climate change/drought are the crop insurance plans. Farmers have the option of purchasing crop insurance in the event that the onset of drought should cause crop damage and economic loss. Most crop insurance programs cover a portion of the average expected yield and require a deductible for management of adverse selection and moral hazard (Skees, Hazell, & Miranda, 1999; Garrido et al., 2011). Functioning insurance market depends on supporting institutions, and social norms related to reporting and monitoring damaged enterprises.

Besides policy-related institutions such as subsidies, farm aid and crop insurance, there are also other important agricultural and rural institutions which play a major role in combating the effects of droughts in particular and climate change in general. Among such institutions one can mention public or private agricultural extension system for know-how building, farm input supply institutions to reduce transaction costs of farmers, agricultural marketing system to shorten the time a product has to spend before being marketed, trade policies and food storage and distribution system to buffer food stocks.

As was already indicated, the success of these adaptation strategies depends on supporting institutions such as available information regarding risks, network of service agencies, and extension support of farmers coping with the subsidized items, to mention a few. An efficient educational system to inform farmers of the pros and cons associated with the government-supported activity, to reduce adverse effects of existing or newly established social norms are necessary.

4. Social norms and performance of institutions

So far we used cases and analyses from the literature to demonstrate available institutions and adaptive strategies (some of which are also institutions) that support adversarial climate change impacts on irrigated agriculture, and types of social norms that have been observed in various communities.

In Section 2 we identified three types of norms: norms that operate in a deterministic environment, norms that are enforced by individuals who sacrifice their own resources, and norms that depend on the source of the resource scarcity—whether or not it is natural or human-made. In Section 3 we identified a subset of five groups of adaptation strategies, some of which could also be in the form of public institutions: provision of publicly developed crop varieties, on-farm adaptive management strategies, irrigation practices and technological modification to infrastructure, water sector policies (institutions); and nonstructural government interventions.

In this section we provide examples for possible interaction of the institutions with a set of social norms that could hamper or enhance their effectiveness. The social norms we include in Table 1 and their impact on the performance of the water-related institutions are only a subset of existing social norms in various communities. The same holds for the number of specific institutions under the main four categories listed.

Table 1
Selected institutions/technologies for adaptation and the social norms that may affect their effectiveness.

Proposed institution/technology and expected effect	Social norm	Likely impact of the social norm on the performance of the institution
	Science and technology	
Drought tolerant crops.	Diet of local population. This may not be correct as in the case of SCUBA rice the flood-resistant SUB1 gene, when transferred into popular rice varieties, allows them to retain their characteristics.	Farmers may resist the use of the new crops because it may mean to change cropping patterns and alter their diet.
Genetically modified crops.	Belief that genetically modified crops are harmful. This norm is driven by belief that the Genetically modified crops may affect the environment and humans. In addition, some of the resistance is rooted to globalization and control by corporations (e.g., Monsanto).	Resistance to adopt the new crop varieties.
	Adaptive management strategies	
Wastewater reuse in irrigation.	The yuck effect norm. More prevalent in developed countries, such as California, where farmers resist the use of recycled wastewater for irrigation.	Eliminates a steady supply of good quality irrigation water.

Table 1
(*Continued.*)

Proposed institution/technology and expected effect	Social norm	Likely impact of the social norm on the performance of the institution
	Adaptive management strategies	
Maintenance and upgrading of existing infrastructure.	Norm of condoning rent seeking behavior of politicians and senior officials. Especially seen in developing countries where political power plays a major role in rural areas.	Preference for investment in large scale projects and limited investment in maintenance.
Maintenance and upgrading of existing infrastructure.	Norm of communal maintenance based on land size or per household contribution in Farmer Managed Systems. Perceived fairness of farmer contribution norms is complementary to the maintenance norm.	Efficient flow of water and availability of water to all farmers in system boundaries.
Limited sustainable extraction.	Strong Monitoring and sanctioning rules. We observe such norms in joint management of aquifers, where clear allocation institutions are not in place.	Sustainability of CPR and availability of water to all participants.
Water Users Associations and User Committees to manage irrigation systems in AMISs.	Norm of political favoritism and rent seeking behavior. This norm does exist as long as there is a strong role for the officials of the AMIS.	Non-equitable power structure and water distribution. Breakdown of system due to lack of user participation and profit maximizing exploitation of resource.
Institution of payment of officials and staff of agencies associated with FMIS by shares of post harvest output.	Norms of utility maximization and sustainable resource use. This norm is more likely to lead to cooperative arrangements in the management of the resource.	Motivates the agents to secure system efficiency and sustainable use of resource, while ensuring equitable water use.
Institutions of land tenure security, fair water sharing rules (land size/cropping pattern based), penalties.	Norms of utility maximization and sustainable resource use. This norm is more likely to lead to cooperative arrangements in the management of the resource.	Self interest motivates the farmers to ensure the resource is sustainably used by all agents and therefore monitoring of the resource use.
Resource allocation in proportion to system maintenance contribution.	Norms of utility maximization and sustainable resource use. This norm exists in societies where sacrifice by individual members is undertaken.	Tail end users of irrigation systems become more invested in the regular maintenance of the system to ensure adequate water provision.
Resource allocation in proportion to system maintenance contribution.	Norm of political favoritism and rent seeking behavior. This norm exists when the society is divergent and polarized.	The skewed power structure may break down the communal maintenance of irrigation system. May also lead to conflict between upstream users and

Table 1
(*Continued.*)

Proposed institution/technology and expected effect	Social norm	Likely impact of the social norm on the performance of the institution
	Adaptive management strategies	
		downstream users. Tail end users would stop maintenance efforts leading to system leakages and subsequent decrease in coverage and agricultural output.
	Water-related institutions	
Trade in water across users.	Casts and inter-societal differences hinder interaction between parts of the society. Typical in certain societies with cast culture	Prevents water from moving to the highest value use.
Water pricing to enhance conservation.	Belief that water is provided as manna from heaven to all. Norms of fairness may be a hindrance. This norm exists in certain societies and is shared not only by the users but also by the government officials.	Prevents interventions aimed at signaling the economic value of scarce water.
Government water extraction rules imposed to ensure minimal extraction	Norms of fair water allocations determined by community leaders.	Cooperative Communal violation of government imposed extraction rules.
Monitoring water use and penalizing overuse of resource.	Norms of seniority in promotions, political favor seeking.	Lack of monitoring and penalties leads to over extraction at system head and no irrigation water for tail end users.
	Other institutions	
Government administered insurance programs.	Government should not be trusted for compensation under crises situations. Norm does exist in countries with weak government services and remote agricultural regions.	Not sufficient number of insured for establishing actuary basis at a reasonable cost.

Source: Authors' evaluation of extensive literature not provided here but available upon request from the authors.

Table 1 suggests that the social norms can be divided into household- and community-level ones, or individual and community-based norms. For example, the belief that genetically modified (GM) crops are harmful is a personal norm that penetrates to the community and can block diffusion of drought or flood resistant crops to a village or a region, influencing the performance of water allocation institutions. Then, a norm of communal maintenance based on land size or per household contribution in farmer managed systems, which is a community norm helps keep efficient flow of water and availability of water to all farmers within the system boundaries. The proper way to address the possible adherence of the performance of the institutions by the existing social norms is a policy challenge. In the last section we provide general suggestions as to how policies should be addressing possible negative impacts of social norms on the performance of various institutions in the irrigation sector.

5. Summary and policy implications

As climate changes and affects the availability of water, mainly through more frequent and longer drought episodes, farmers in drought-hit regions suffer the most. Observations and analyses of various publications cited in this paper suggest that regions facing similar water scarce situations will be able to sustain them to different extents. As suggested by some of the publications, including the meta analysis by World Bank (2010a) and the background reports it cites, institutional capacity plays a major role in the resilience of groups and communities to sustain hard, prolonged droughts. This paper added another aspect to the discussion of performance of institutions in light of water scarcity. Namely we assert that social norms both at the individual and the community levels play an important role in the well-performance of institutions.

Using various examples of institutions that were designed to address impact of scare water on the performance of the irrigated agricultural sector, we identified some of the social norms that can enhance or impede impact of the institutional arrangements on the performance of the sector, and thus, call for policy intervention that can align the institutional arrangements with the existing social norms for an improved performance of the institutions and through them the improved performance of the adaptation strategies.

While not the focus of this paper, policy-makers might be interested in alleviating norms-inhibiting institutions to improve the performance of the institutions through better interaction with the social norms. They can do it via incremental modifications of institutions to fit the social norms with which these institutions interact. Policy makes can also provide incentives to communities or individuals to modify their norms so that they support the institutions. Also, government investments would be more efficient by taking into account the existing local social norms and institutional arrangements. These policy interventions and how effective they can be in making institutions perform better will be the subject of another study.

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