# Water governance under uncertainty: the case study of Users' Associations in Lebanon

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## Abstract

*Governance of water use for irrigation is a challenging topic, due to alteration in climatic patterns and the resulting resource scarcity in arid and semi-arid regions. Success stories can turn quickly into failures when significant disturbances occur. This contribution focuses on the institutional analysis to highlight factors which enable or constrain the role that Lebanese Water Users' Associations can play to tackle current and expected water shortage conditions. Furthermore, by integrating Ostrom's design principles and a dynamic game approach, the study examines the robustness of participative institutions and their operational rules when dealing with climate change generating uncertainty about availability of water resources at local level. Water governance can find a pivotal actor in local institutions (e.g. users' associations) not only if their organization is based on social cohesion, reciprocity, trust, information sharing and accountability concepts, but also and preliminarily, if higher-level external conditions like public recognition and control, inclusion in collective decision-making processes, and operative subsidiarity are met.*


***Keywords:*** *common pool resources, water use for irrigation, water scarcity, water user' association, governance.*


## Résumé

La gouvernance de l'utilisation de l'eau d'irrigation représente un défi majeur alors que le changement climatique et la pénurie des ressources provoquée par ce dérèglement affectent les régions arides et semi-arides. Les bons exemples peuvent soudainement se transformer en des échecs quand des perturbations interviennent. Dans ce travail, nous proposons donc une analyse institutionnelle pour mettre en évidence les facteurs qui stimulent ou bien limitent le rôle que les Associations des usagers de l'eau peuvent jouer au Liban dans les conditions actuelles et futures de pénurie d'eau. En plus, en intégrant les principes d'Ostrom et l'approche des jeux dynamiques, nous allons évaluer la robustesse des institutions participatives et leurs règles opérationnelles face aux aléas climatiques qui génèrent une incertitude dans la disponibilité des ressources en eau à l'échelle locale. Les institutions locales (par exemple, les associations des usagers de l'eau) peuvent devenir un acteur incontournable pour la gouvernance de l'eau non seulement si elles réussissent à promouvoir dans leur organisation les principes de cohésion sociale, réciprocité, confiance, partage de l'information et responsabilité, mais aussi et avant tout, si d'autres importantes conditions externes interviennent telles la reconnaissance et le contrôle par les institutions publiques, l'inclusion dans des processus collectifs de prise de décision et de subsidiarité opérative.


**Mots-clés:** ressources en propriété commune, utilisation de l'eau pour l'irrigation, pénurie d'eau, association des usagers de l'eau, gouvernance.

## 1. Introduction and conceptual background

Water scarcity is a globally spread phenomenon which is already affecting 1.2 billion people and is expected to impact 1.8 billion people by 2025 (UN-Water, 2007). It is well- known that its definition includes both *water stress* and *water shortage or deficit* concepts. The former defines a temporary hindrance to water source access, while the latter one describes a structural change in the usual water availability that can be caused by altered climate patterns, and by quantitative and/or qualitative (pollution) resource overuse.

Water scarcity has become an emerging huge problem in arid and semi-arid regions, like in the Middle East and North Africa (MENA) region which is explored in the present study. With regard to this area, literature shows that misallocation and mismanagement have largely contributed to current water stress and limited ability to tackle the expected water shortage (Bou-Zeid and El-Fadel, 2002; El-Fadel *et al.*, 2012). In fact, there now exists a broader consensus about the heavy impact that climate change will have in this region and the resulting increase of dry days (Sowers *et al.*, 2010; IPCC, 2014). Nevertheless, due to the spatial and temporal uncertainty around the expected climate effects, local public authorities usually tend to respond to water scarcity by supply-oriented solutions (e.g. infrastructures), rather than to addressing water governance and management issues.

In addition, according to recent studies on water deficit in Lebanon, population growth and economic development are expected to put additional pressure on scarce surface water resources in a context where current consumption levels are already not sustainable (El-Fadel *et al.*, 2000; MoE/UNDP/ECODIT, 2011). Household and industrial water demand is in fact competing with the primary sector requirements - driven by the expansion of irrigated agricultural land - amounting to the 60% of the water use in Lebanon (FAO, 2014). Given the system fragility of the system, any alteration in climatic patterns leading to temperature increase and rainfall reduction would greatly exacerbate the existing difficulties, especially for the irrigation activities (Bou-Zeid and El-Fadel, 2002). In order to respond to future water shortage, the Lebanese government has launched a ten-year infrastructural plan based on the construction of dams, artificial ponds, and irrigation channels (NPMPLT, 2005). Besides public intervention, research workes focused on water

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use in agriculture in Lebanon (Gharios, 2009; El Chami and Karaa, 2012; Lamaddalena and Khadra, 2012) advocate that farsighted governance initiatives should be undertaken to foster direct and responsible participation of farmers in designing, implementing and managing irrigation programmes. To that end, local institutions (the Lebanese Water Users' Associations, WUAs) could play a strategic role. Indeed, not only are WUAs widespread in the country's rural areas, but they have also been demonstrating that proper governance schemes can ensure efficient and sustainable water management (Gharios, 2009; Lamaddalena and Khadra, 2012). However, it must be highlighted that the functioning and potentiality of these Lebanese institutions have not been analysed yet and that, in particular, the rules adopted to regulate members' decisions on water scarcity are, to a great extent, still unexplored.

In order to bridge the knowledge gap concerning the WUAs' role and behaviour, this study will follow the way paved by Ostrom (1990) with her ground-breaking work "*Governing the Commons*". The Author proved that individuals are keen to establish agreed-upon rules and strategies to manage and use common pool resources (CPRs). However, when scenarios are characterized by increasing environmental and socio-economic pressures on CPRs availability and quality, conflicts can arise among the economic parties concerned. In such a context, local associations of users can favour renewed and jointly agreed arrangements on the sustainable access to resources (Anderies *et al.,* 2004). The importance of the role of local users' organisations in the governance of CPRs is largely recognised in the literature and supported by extensive field works and analyses (Ostrom, 1990; Gibson *et al.*, 2000; Madani and Dinar, 2012). Moreover, under certain conditions, self-governing institutions have proved to be efficient and capable of learning lessons from their mistakes and adapting their behaviour to changes, thus providing feasible solutions over time (Gentle *et al.*, 2013). With reference to water management and use, jointly organised irrigation systems often prove to be successful in terms of governance and capacity to counteract drought (Ostrom, 1992). Furthermore, in case of periodical uncertainty about water availability, players can take advantage from their past experiences opting for cooperative behaviours and coordination to combat exogenous threats (Anderies *et al.*, 2013). However, institutions can fail when rapid or significant changes occur: early investigations into common goods games have highlighted that collaborative behaviours can be compromised by uncertainty (Gustafson *et al.*, 2000), and that lack of trust and inequality of earnings can reduce the adaptive capacity of the community (Janssen and Anderies, 2013). This is quite a frequent event for local water users' organizations: their effectiveness is increasingly impaired and undermined by instability of socio-economic conditions, by climate variation, and by the resulting effects on irrigation systems (Anderies and Janssen, 2011).

Despite increasing interest in the evolution of self-governing institutions concerned with changing conditions over the last years (Kim, 2004; Ostrom, 2013), findings and solutions cannot be easily generalized. It is still crucial to extend research to different contexts and, in particular, to gain knowledge about the relationships between water scarcity, governance and management of irrigation systems. Taking into account the complexity that characterizes the dynamics between participative institutions and irrigation systems, as well as the revealed analysis needs, the main goal of this study is to cast light on local institutions in arid and semi-arid areas (Lebanese WUAs) and explore their ability to adapt their role and rules (e.g.: economic incentives, information schemes, participative procedures, …) when facing water scarcity.

With this aim in view, in the first section Lebanese local institutions will be described by means of the "Institutional Analysis and Development" framework. In the following section, the information collected will be reviewed in light of Ostrom's design principles - a set of features that characterize resilient local institutions (Ostrom, 1990) (3.) - in order to gain a better understanding of the WUAs robustness, and to apply a theoretical dynamic game for the analysis of possible WUAs functioning in water shortage conditions.

## 1.1. The Institutional Analysis and Development framework

In order to analyse the WUAs and the related irrigation systems, this study reports a set of case studies gathered by Gharios (2009), Lamaddalena and Khadra (2012), and focuses on Ostrom's approach (2005): the so-called "Institutional Analysis and Development" (IAD) framework (attributes of the context, actors involved, past interactions and outcomes).

The main purpose of the Institutional Analysis and Development (IAD) framework is to analyse – at multiple level – the governance of common resources, the related strategies and the resulting implications for users' behaviour (Ostrom, 2005). A metatheoretical language will allow the organisation of diagnostic and prescriptive surveys. Being designed to increase knowledge of complex socio-economic systems, IAD investigates the effects that rules, biophysical and economic conditions, and community attributes have on the "structure of the action arena", i.e. the IAD's reference conceptual unit, in order to analyse the actors' behaviours and institutional arrangements. The so-called "action arena" is therefore the social place where participants take decisions considering potential outcomes, action-outcomes linkages and interactions as well as the expected costs and benefits. Furthermore, the "structure of the action arena" provides relevant information which can be examined by adopting different methodological approaches (e.g. Game Theory) for a deeper understanding of governance and management of common resources.

For the purpose of this research, the IAD framework is applied to study the context and the main issues that describe the "action arena" where Lebanese WUAs and the associated farmers operate, the underlying interrelationships, and the current outcomes. The body of evidence is analysed through an integrated approach based on Ostrom's design principles (3.) and the dynamic game theory (Madani, 2010) to gain an in-depth insight into the impact of water scarcity on local institutions' and users' behaviours.

# 2. Local institutions and governance of irrigation systems: the Lebanese Users' Associations

## 2.1. Overview of the Lebanese setting

Lebanon was deeply marked by several decades of conflicts and all efforts are now directed towards restoring stability and wellbeing. The conflict effects are still being felt today. Mention should be made here of some issues concerning irrigation systems management. In Lebanon, rainfall is abundant i.e. 800 mm/year compared to 252 mm/year in Syria and 111 mm/year in Jordan (Comair, 2007; MoE/UNDP/ ECODIT, 2011). Nevertheless, a growing fresh water demand for irrigation, household and industrial use is already causing water deficit estimated at about 388 $Mm^3$ during the summer months. In addition, average temperatures are expected to increase with a rise of approximately 1°C on the coast to 2°C in the mainland by 2040, and 3.5°C to 5°C by 2090, while projections on rainfall indicate a decrease of 10-20% by 2040, and of 25-45% by 2090 (MoE/UNDP/ECODIT, 2011). The combinatory effect of these phenomena will cause an extended water shortage. To face this challenge, the Lebanese government launched in 1999 a ten-year water master plan for investments and, in 2000, an institutional reform to regulate water use in the different sectors. So far, these have remained unfulfilled ambitions, in particular as regards the new institutions which should have replaced the old ones and traditional customs and habits which still regulate water allocation (Comair, 2007).

### 2.1.1. Water governance in Lebanon

The importance of water governance has long been recognized in Lebanon to spread efficient water management solutions, and to avoid conflicts. The Majallah code (1839) codified for the first time customs, habits and concessions. Afterward, water resources were declared to be public properties and water rights were established. Some specific limitations were introduced regarding private ownership and acquired rights on water resources (heritage, donation, and purchase done before 1926, due to the Majallah code allowing for the acquisition of goods without an owner, such was water). In 1930, the Government of Lebanon issued a decree setting out that water in a private land is the owner's property. Since then, several attempts at reorganizing a water system were made but, due to long-lasting instability, the reform was never accomplished. More recently (2000), a new institutional framework for water governance in Lebanon (Comair, 2007) was established at national level bringing together:

- The Ministry of Energy and Water (MoEW), responsible for the definition of national water policy, national master plan and of execution of hydraulic projects;
- The Ministry of Agriculture (MoA), responsible for monitoring of irrigation water quality and coordination of research, extension services, and farmers' training;
- The Water Establishments (WEs), regional entities operating (in Beirut-Mount Lebanon, in North Lebanon, in South Lebanon and in Bekaa) under the control of the MoEW, and responsible for potable and irrigation water consumption, waste water issues, financial investments, project design, operation and maintenance, and tariff collection from water users. Currently, some WEs functions (e.g. networks and equipment management) are performed by former institutions, namely the Local Committee and the Irrigation Committee;
- The Litani River Authority (LRA), a body tasked with design and financing of water related projects in the Litani River Basin (e.g. domestic, irrigation, and hydropower water schemes), whereas the South-WE is responsible for local potable and waste water management issues.

Despite the clearly defined roles and responsibilities, functions and initiatives of the above institutions are often poorly integrated, and not enough effective to ensure a suitable water governance.

### 2.1.2. Water governance and management and Users' Associations

Lebanese Farmers' communities have long-lasting tradition as regards water use agreements and irrigation systems management, although the only existing law, which regulates at national level the WUAs establishment and dates back to the French mandate (1926), has never been enforced due to its complex framework. Recently, within its National Water Sector Strategy (2012), the MoEW has explicitly assigned a role to the WUAs for the operation and maintenance (O&M) of secondary and tertiary irrigation schemes, and for water fees collection, but up till now no official legislation has been put in place. As a result, farmers wishing to organize irrigation systems on a collaborative basis currently prefer to set up agricultural cooperatives, as requested by the MoA. Cooperatives must adopt their statutes defining the operational rules and management structure, namely a general assembly of all the members for the election of the Board of Directors. Consequently, sharing of roles and responsibilities amongst central institutions and local organizations (WUAs and cooperatives) is not clearly assigned and defined and this leads to competence overlapping in water management. Moreover, the delay in water reform implementation has prevented to date conflict resolution. Furthermore, data indicate that only 3% of Lebanese farmers declare that they belong to any collective organisation (MoA, FAO, Cooperazione Italiana allo Sviluppo, 2012), a figure which undoubtedly mirrors the weakness of local institutions in the Lebanese agricultural panorama, and highlights the organizational limits hindering participatory and collaborative use of water resources for irrigation. As a consequence, ready to use information and analytical tools, aimed at supporting policies for crafting well-functioning local institutions, can be strategic in a context of increasing water scarcity.

## 2.2. Institutional Analysis of Lebanese local institutions

The Lebanon participative institutions (WUAs) operate locally to manage available water resources, in response to the poor infrastructure maintenance and the proliferation of illegal wells which bring about uncontrolled water overuse and increasing allocative inequalities. All the five local institutions described below (the Agricultural Cooperative Association of Mchaytiyyeh, the Lake Share Communities' Union in South Bekaa, the Irrigation Water Users' Association of Jabboule, the Marjeyoun-Khiam Plain Water Users' Association, the Btedhi Water Users' Cooperative) have a legal status and their institutional organizations represent the formerly defined WUA. The next paragraphs will cover in more detail data and information provided by Gharios (2009), Lamaddalena and Khadra (2012).

### 2.2.1. "Agricultural Cooperative Association of Mchaytiyyeh"

*a) Community attributes:* the small valley of Mchaytiyyeh is karstic and water has always been scarce there. Farmers have been used to growing only rainfed crops, mainly cereals, or digging their own wells which became too expensive due to the aquifer depth. With the help of donors, it was possible to dig an 8 km well upstream the village, where water was available thanks to direct source access. To store the extracted water, farmers built a 25,000 $m^3$ reservoir, with a 1 km capacity, downstream. In order to supply water to the plots around the village, farmers built two pressurised main canals. Farmers could then irrigate their plots and increase the productivity of their crops, such as apples, and reclaim some more lands to grow on the mountains. The driving force establishing this WUA was a Lebanese official willingness to help the villages. Besides, farmers - tied together by family links – demonstrated that they understood the power of collective action in regulating water use through the newly built canals.

*b) Institutional setting:* in Mchaytiyyeh there are internal laws establishing an administrative council and a surveillance committee, elected every two-year. A caretaker is appointed to check compliance with irrigation schedule and water supply. In case of violation, the offender is first warned and then, when appropriate, punished accordingly. Communication is ensured using both letters and mobile phone messages. Farmers pay a fee to the association for each drip point and proportional to production. In return, the WUA provides additional services such as: common tractor, cooperative fridge, fertilisers and marketing services.

### 2.2.2. "Lake Share Communities' Union in South Bekaa"

*a) Community attributes:* the main goal of the South Bekaa community is to efficiently exploit water under the South Bekaa Irrigation Scheme (Canal 900) as a part of the national irrigation scheme plan of the Litani River Authority (LRA). Canal 900 consists of 18 km underground-pressurised canals which deliver water over a total area of 2,000 ha. The LRA is in charge of Canal 900 management and the Lake Share Community has been created for Canal 900 O&M. Initially, not all farmers in the area joined the community and non-members were supplied water from the scheme regardless of their membership. Hence, WUA membership was increasingly viewed as useless by many farmers who started to break the rules, to eliminate flow regulators, and to misuse the hydrants. As a consequence, many tail-end farmers could not receive water although they were members of the WUA. An awareness raising campaign, supported by the local municipality, helped improve the situation and 40 farmers eventually joined the WUA. Yet, the local community is heterogeneous and there are not ties, like family links, keeping them together. Furthermore, farmers are poorly educated. All these factors are considered to be behind the low success rate of the Lake Share Communities' Union.

*b) Institutional setting:* the cooperative has internal laws establishing an administrative council elected every two years. Conflicts are resolved outside the WUA, involving the Municipality and LRA.

### 2.2.3. "Irrigation Water Users' Association of Jabboule"

*a) Community attributes:* the irrigation community was created by international donors to address rural development in the semi-arid climatic area of Jabbouleh (less than 400 mm/year rainfall), where agricultural activities generated inadequate yields. With a view to optimising the available water resources, the system built in Jabboule included a hill lake of 20,000 $m^3$ in connection with a collective pressurised irrigation network covering 100 ha, and five 2,000 $m^3$ reservoirs, each feeding an area of about 20 ha. The capacity of each reservoir corresponds to the total amount of water rights of the farmers connected to the pool. To effectively manage the resource distribution, an electronic system (the so-called AquaCard®) was introduced besides a mechanisation process. The local community can be considered quite homogeneous since all farmers rent the lands from the same owner (the Catholic Diocese).

*b) Institutional setting:* in Jabbouleh, farmers jointly elaborate the seasonal irrigation schedule; since the systems effectively allow controlling water level, before the start of the irrigation period they meet to agree upon the amount of water which will be allocated to each user. The electronic card mentioned earlier works as a controller because taking more water than the amount formerly agreed upon and paid for is not allowed and therefore, conflicts are significantly reduced.

### 2.2.4. "Marjeyoun-Khiam Plain Water Users' Association":

*a) Community attributes:* in a post-conflict operation in Marjeyoun-Khiam area, international cooperation developed a plan for to revive the local rural economy. The land is a fertile plain, with many water springs and the Dirdara

natural pool is considered the main water source for irrigation. Prior to Israeli occupation, concrete canals fed the cultivated land and a caretaker had the responsibility for equitable water distribution. When the Israeli troops left, after 22 years, the system was no longer usable and the land neglected. Farmers exploited unlicensed wells and some of them put their pumps directly into the pool. The intervention of international cooperation in the area restored the Dirdara irrigation network, replacing old canals with underground pipelines, provided with flow meters measuring the amount of water delivered throughout the territory. The WUA was thus created to manage the newly built system and monitor compliance with the rules adopted. Farmers could soon shift to more profitable crops like stone fruits and water was available also to the tail-enders.

*b) Institutional setting*: in Marjeyoun a caretaker is responsible for water scheduling and distribution and farmers are involved in the association management. The strong political support and the measures taken to forbid private wells have facilitated joining the irrigation scheme.

### 2.2.5. Btedhi Water Users' Cooperative

*a) Community attributes:* in Btedhi district, agriculture is the main economic activity. Long and severe draught periods had increased desertification of the area and the farmers, incapable of regaining fertile land, started to flee the district. Water was potentially available, in excess during winter and spring seasons, but the community was unable to store it for the dry period. For this reason, the intervention of international donors was focused on two main actions: enhancement of infrastructure with the construction of an 85,000 $m^3$ reservoir and the installation of a tertiary pressurised distribution network, and the set-up of an association to collectively manage and operate the system.

*b) Institutional setting:* in Btedhi, all villagers are eligible for membership (residents or non-residents) and all the shareholders have the same weight and voting power, regardless of the shares they own. Members elect the Management Board and the Foresight Committee, they pay a cost for water use, and are responsible for network protection and for setting of and compliance with the irrigation calendar. The Board is responsible, among other duties, for conflict resolution. In this community there is an enforcement system for those members who fail fulfilling their obligation. The WUA is in general responsible for O&M and fees collection. These fees are allocated to pay the cost of water supply to the Government and of the caretaker and they are earmarked for unforeseen emergencies.

### 2.2.6. Outcomes and feedbacks of WUAs

The five areas analysed were affected in the past by water scarcity due to poor resource governance and management and lack of infrastructures which had ultimately led to a widespread land abandonment. The establishment of WUAs contributed to significantly change the state of play by allowing access to water to all farmers, bringing back those farmers who had fled in wartime, and favouring more profitable crop production. Farmers could reclaim additional land as greater efficiency was achieved following the introduction of modern irrigation techniques like drip and sprinkler systems. Although water scarcity is still a problem in South Bekaa, agriculture is currently a profitable activity in the other regions analysed and farmers are committed to strengthening the WUA's management capacity to increase business competitiveness and sustainable use of water resources.

## 3. Methodological approaches

Multi-method criteria have been adopted throughout this study to analyse the behaviour of institutions and small scale-irrigation systems and better understand their adaptation capacity (Ostrom, 1990; Janssen and Anderies, 2013). In line with this approach and following the "action arena" concept included in the IAD framework, WUAs' institutional structure is analysed: first, the "design principles" defined by Ostrom (1990) are applied to assess their robustness. This feature refers to the capacity of a local institution to keep its own profile and mission (function, structure, feedbacks and therefore, identity) when experiencing shocks. Secondly, a theoretical dynamic game is developed to discuss how water resource availability and use might affect farmers' strategic interactions and Lebanese WUAs governance role.

### 3.1. Design principles

To define the attributes which enable an institution to achieve an appropriate and durable role in sustainable management/governance of common-pool resources, Ostrom (1990) proposed a set of conditions, called "design principles":

1. "Clearly defined boundaries: Individuals or households who have the right to withdraw resource units from the CPRs must be clearly defined, as must be the boundaries of the CPR itself."
2. "Congruence between (CPRs) appropriation and provision rules and local conditions: Appropriation rules restricting time, place, technology, and/or quantity of resource units must be related to local conditions and to provision rules requiring labour, material, and/or money."
3. "Collective-choice arrangements: Most individuals affected by the operational rules can participate in modifying them."
4. "Monitoring: Monitors, who actively audit CPRs conditions and Appropriator behaviour, are accountable to the appropriators or are the appropriators."
5. "Graduated Sanctions: Appropriators who violate operational rules are likely to be assessed graduated sanctions (depending on the seriousness and the context of the offence) by other appropriators, by officials accountable to these appropriators, or both."
6. "Conflict-Resolution Mechanisms: Appropriators and their officials have rapid access to low-cost local arenas to resolve conflicts among appropriators or between appropriators and officials."
7. "Minimal recognition of rights to organise: The rights of appropriators to devise their own institutions are not challenged by external governmental authorities."

8. "Nested enterprise: Appropriation, provision, monitoring, enforcement, conflict resolution, and governance activities are organised in multiple layers of nested enterprises."

Many research works (Ostrom, 1992; Mosse, 1997; Leach *et al.*, 1999; Blaikie, 2006; Bastakoti and Shivakoti, 2009; Cox *et al.*, 2009, Baggio *et al.*, 2014) tested the above principles reaching different results and evidence. Mosse (1997) and Leach (1999) suggested that these principles are too much abstract when compared to the complexity of the environmental system and to the social domain where actors behave. Blaikie (2006) argued that it could be dangerous to presume the superiority of scientific generality over the empirical context. Cox (Cox *et al.*, 2009) showed that in most cases the principles are consistent with the original intended scope. A similar conclusion is reached by Baggio (2014) who stressed the helpfulness of the approach in identifying important patterns across a range of situations, and in offering an interpretation which is a key to understanding the complexity of the socio-economic-environmental systems. In particular, the Author pointed out that the principles should be analysed as a whole, and that their importance and cognitive contribution depend on the qualities of the investigated resource. Considering the great scientific interest of the approach and its consistency with the objectives of this study, Ostrom's principles were adopted to analyse and evaluate the robustness of Lebanese local institutions (WUAs) as specified above.

## 3.2. Dynamic game theory

For the purpose of this research, the IAD framework was integrated with a non-cooperative game-theoretic approach to study how changing contexts (water availability uncertainty) impact rational players' (producers') decisions, how they interact and behave to adapt their activities (Ostrom *et al.*, 1994), and how institutions can reshape their governance. The game theory gives the opportunity to illustrate how strategic interrelations among players result in overall outcomes which are not necessarily Pareto-optimal and might not have been intended by any of the players (Nash, 1950). In other words, the stakeholders' self-optimising attitude frequently results in a non-cooperative behaviour even when a cooperative behaviour is more beneficial to all parties.

In order to analyse farmers' decisions and strategies (Madani, 2010; Podimata and Yannopoulos, 2015), and governance solutions (Ansink and Ruijs, 2008) in water use conflict contexts, the game is extended to a dynamic framework in which water conditions are worsening over time. In this scheme, any variation in the resource availability affects users' behaviours. The resulting new outcomes feed back onto participants' choices altering again their results. While in the short run users can simply change their strategy and routine decisions to achieve the desired outcome, in the long run unsatisfactory or unfair outcomes can raise questions and conflicts requiring a review of rules and institutional settings to achieve a more efficient and equitable resource allocation.

Aiming at simulating how water shrinkages (e.g. due to climate change) reverberate on producers' choices, and how these decisions are mutually affected and evolve over time, the study - following Madani (2010) - adopts a dynamic two-by-two water resource game structure. Changing conditions and their impact on the players' outcomes imply the necessity to adapt the rules of local institution to ensure an appropriate resource use.

Figure 1. *The IAD framework (Ostrom, 2005).*

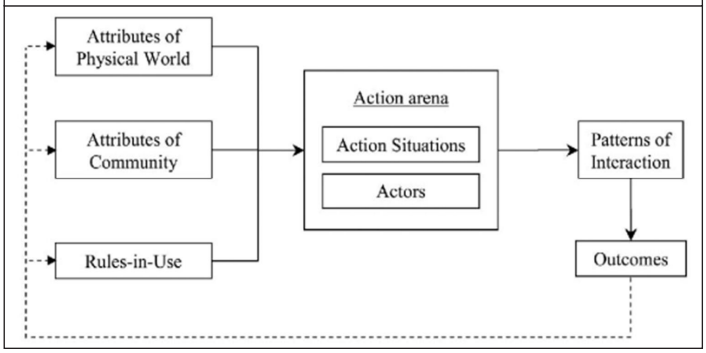
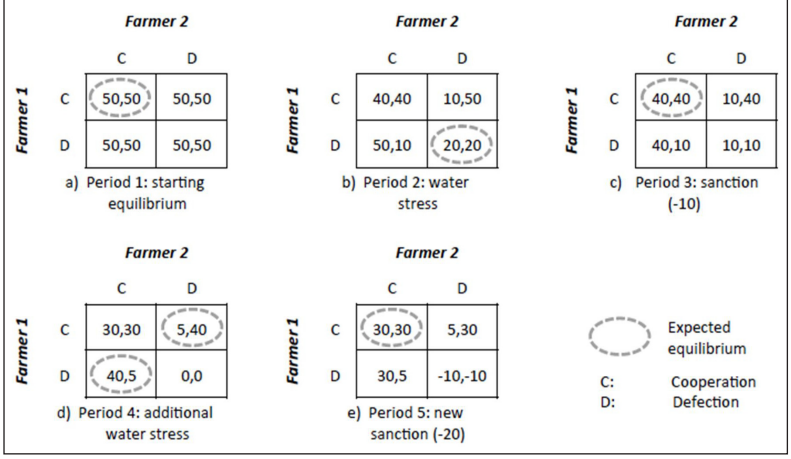



Figure. 2 illustrates a possible evolutionary scheme of irrigation rules in a participative institution, such as the WUAs, when water availability is reduced. Only two farmers (players), with symmetric production functions and payoffs, are showed; information is assumed to be perfect and two players' decisions are assumed to be simultaneously adopted; the sector choice as well as the technological and market conditions are supposed to remain unchanged. Players can decide whether they should cooperate (i.e. following the WUA rules and limiting water consumption to the assigned volume) or defect (i.e. using higher water volumes than allowed in order to get higher payoffs). Payoffs are expressed in cardinal form in order to describe, in qualitative terms and with no specific reference to the case studies, the kind of interactions between the players. In the following sections, the five Lebanese WUAs have been compared through this general framework to analyse their state, the nature of the existing/ possible conflicts, their expected dynamics and to detect feasible solutions.

In particular, in the starting period 1, the WUA is assumed to manage a water volume congruent with the requirements of its members: users are allowed to reach the planned crop yields and the expected payoffs from their production activities (i.e. 50). In this case, there is no reason to violate the association's rules, and controls and sanctions are not necessary.

In contrast, the situation can change when shrinkages of water availability in the reference area occur (period 2). In this context, the WUA has to limit the water volumes assigned to each farmer, whose payoffs decrease (i.e. 40) due to the resulting production decline. However, farmers can choose to defect new rules in order to consume as much water as necessary to keep the desired yields and payoffs. If producers decide to disregard the association's regulations, too much water will be used for irrigation and the system will collapse. According to the specific conditions, different forms of failure can arise: for example, a long-term break-down can be due to a long-lasting lowering of the water table level whereas a short-term break-down can occur during a limited period following a

Figure 2. *Possible evolutionary scheme of the irrigation rules in a participative institution.*




seasonal water overuse. In all cases, the game theory suggests that defection is the strictly dominant strategy for both players, and that a Nash equilibrium can be reached at point (D, D) where each of them would expect to be better off regardless of what the other player does. This is a classic result of the so-called prisoner's dilemma game structure that describes the situation known as tragedy of the commons (Hardin, 1968): in fact, the players' payoffs are lower (i.e. 20) than what they would obtain through a cooperation strategy.

In such an instance, the local institution (WUA) can adopt (mandatory or governance) measures to implement better resolutions in terms of water resource use and farmers' payoffs. If an appropriate financial sanction is applied to defectors (with subsequent monitoring), the farmers' behaviour should change. In the example under examination (period 3), a sanction equal to 10 (an amount commensurate with the difference between the starting theoretical payoff and the one achievable through cooperative behaviours) should be sufficient to eliminate any incentive to defection. In this case, the cooperation scheme (C, C), the only Pareto-optimal outcome, proves to be stable.

Should a further decrease in total water availability occur, the game structure would change again (period 4). In this new condition, despite the application of a financial sanction, the farmer will obtain a higher payoff by adopting a defecting strategy (i.e. 40 vs. 30) provided that the second farmer still pursues his cooperative strategy. However, unlike the previous prisoner's dilemma structure (period 2), if both players decide to defect, the resulting outcome (due to the cumulative effect of sanction and water shortage) will be the worst for the two players. It is well-known that the former structure (defection vs. cooperation) is defined as a "chicken game" which can lead to two Nash Equilibria and where with one of the two players wins and the other loses. If the two players have the same characteristics and act under the same conditions as supposed, it will not be possible to define who will defect first, but any possible difference (e.g. crops, technologies, etc.) between the twos could explain such a result. Again, the WUA should intervene by reinforcing the sanction (at least 20, in the conjectured case) in order to eliminate incentives for defecting behaviours (period 5).

## 4. Findings and discussion

Findings concerning the integration between the "design principles" and the dynamic game theory approaches allow to analyse and compare the robustness level and quality for the five Lebanese WUAs (Table n. 1), and to depict how their rules and governance schemes can evolve under a scenario of changing water conditions and reacting farmers' strategies and behaviours.

### 4.1. Design principles: robustness of Lebanese WUAs

Lebanese WUAs prove to be mostly fragile, mainly due to the lack of institutional recognition by the Lebanese administration at National, Regional or Local level. This explains why they do not participate (or, if they do, they are powerless) in the processes leading to the definition of public choices and the development of collective rules required for efficient and equitable governance and management of water resources.

*Design principle 1. Clearly defined boundaries:* most Lebanese WUAs have quite clear boundaries with the exception of South Bekaa where not all farmers are members of the association. In South Bekaa, non-members get water, but many of them, during their irrigation interval, exceed the intake needed and agreed. This behaviour prevents other farmers and WUA members from receiving their water volume. The farmers realise that their membership is useless and this generates the problems previously described in section (2.2.2). Limitations on water use are a pre-requisite for the successful establishment of a WUA which would otherwise be doomed to fail.

*Design principle 2. Congruence between appropriation and provision rules and local conditions*: in most of the reviewed cases, WUAs provide services to their members as a reward for the payment of operational fees. Rules vary on a case-to-case basis. In particular, in Mchaytyyeh farmers share maintenance costs and reward the WUA with a fee proportional to the number of drip points and to the yearly yield. In return, they receive some supplementary free services: a caretaker responsible for monitoring and controlling water distribution and compliance with allocation agreements (in Marjeyoun as well), a tractor to be used collectively, a fridge to store the fruit intended for sale, assistance and marketing advice. In contrast, in South Bekaa the WUA is not able to provide additional services to its members and farmers get therefore the feeling that membership is useless. This further increases the possible failure of the WUA.

*Design principle 3. Collective-choice arrangements*: at present, the Lebanese WUAs do not have a legal basis given the lack of a specific legislation. Furthermore, they are not at all, and in any event, involved in joint decision-mak-

Table 1 - *Design principles and Lebanese WUAs.*

| | Mchaytiyyeh | South Bekaa | Jabbouleh | Marjeyoun | Btedhi |
|---|---|---|---|---|---|
| 1. Defined boundaries & membership | Yes | No | Yes | Yes | Yes |
| 2. Congruent rules | Yes | No | Yes | Yes | Yes |
| 3. Collective choice | No | No | No | No | No |
| 4. Monitoring | Yes | NA | Yes | Yes | Yes |
| 5. Graduated sanctions | Yes | NA | NA | Yes | Yes |
| 6. Conflict resolution mechanism | Yes | No | NA | Yes | Yes |
| 7. Recognition of rights | Yes | Yes | Yes | Yes | Yes |
| 8. Nested enterprises | No | No | No | No | No |
| **Institutional performance** | **Fragile** | **Failure** | **Fragile** | **Fragile** | **Fragile** |

ing processes. Even though the MoEW prepared a specific plan to involve the WUAs in the governance and management of water resources at the secondary and tertiary level, and the Integrated Water Resource Management approach, introduced in the country, clearly assigns a role to this form of organisations, the Lebanese WUAs and their members do not participate in collective choice arrangements. In this respect, Ostrom (1992) argues that this principle is strongly correlated with successful governance and management of common pool resources, especially when dealing with varying environmental conditions. This condition being disregarded, all the Lebanese WUAs are fragile and the farmers are not in the position, for example, to tailor rules according to local conditions.

*Design principle 4. Monitoring*: in Lebanese WUAs, a professional, hired by the association or by the farmers, is generally tasked with monitoring activities. However, Jabbouleh is an exception. In the irrigated land where the AquaCard® system has been adopted (2.2.3), the farmers have no possibility to free ride or cheat. Monitoring is a service provided by the local association to its members and it is included in the farmers' fee paid to the WUA.

*Design principle 5. Graduated sanction:* in the case studies, rule violation and sanctioning are very rare. Defectors can be subject to graduated penalties in accordance to the level of their misconduct (in particular, in Btedhi a reduction of water volume is applied to free riders), but sanctions are normally limited. Probably, favourable collaboration conditions, revived agricultural capacity, and appropriate distribution of water resources are some of the factors which may encourage the commitment to the rules. Only in South Bekaa (2.2.2), where farmers show a weak feeling about their participation in the WUA, cases of defections are observed. Furthermore, always in South Bekaa external actors, like the municipality or the LRA, are involved in sanctioning the defectors, while Ostrom (1992) suggests that in robust organisations this mechanism should be operated by farmers themselves through their association and not from outside.

*Design principle 6. Conflict resolution mechanism:* in the cases reviewed, the internal negotiation system is either nested in the WUAs management structure or, as it occurs in South Bekaa, external actors - like the municipality or the LRA - are involved in conflicts resolution. Once again the observed positive experiences and results achieved in general by the WUAs are most probably reducing the need for activating this mechanism.

*Design principle 7. Minimal recognition of rights to organise:* no regulatory measures are currently in place to formally recognize to Lebanese Water Users' Associations the responsibility for irrigation systems governance. For this reason, the existing WUAs make use of a ploy to act as local institutions by leveraging on their role of agricultural cooperatives under the MoA's regulatory provisions. This situation generates an overlapping of competences between MoEW and MoA. As a consequence, any future legislative recognition of the WUAs operating in the country should take this condition into consideration as it hampers the development of WUA and the deployment of water governance schemes at secondary and tertiary level.

*Design principle 8. Nested enterprise:* in Lebanon, farmers and their local organisations are not yet involved in any decision-making process at any level and, therefore, this principle is not applicable to the reviewed case studies.

## 4.2. Dynamic games

The WUAs' profile and degree of robustness resulting from the design principles clearly indicate that knowledge is needed to develop a dynamic game and to study farmers' decision-making strategies and adaptation of governance rules when facing water restriction scenarios.

The farmers' choices observed here are generally regarded as the result of stable technical and economic conditions, consolidated practices and planned production activities and, consequently, current water consumption identifies a starting equilibrium among users (Figure 2, period 1). This is true for Mchaytyyeh and Marjeyoun, where resource availability, irrigation network, producers' commitment and institutional setting show a particular congruence (design principle 2), while the only deviation perceived in the state of play is the farmers' reclamation of additional lands in order to expand production. In Jabbouleh, a technological innovation (the AquaCard® system) has been adopted to monitor water use for irrigation, and to favour and/or restore cooperation when the resource is scarce (design principle 4.). For this reason, may that the likelihood for the afore-mentioned WUA to start up is higher in the "water stress" period. The period 3 of the game theory scheme ("sanction") seems to identify the initial state for Btedhi, where non-cooperating farmers can be sanctioned through a cut of water supply, and for South Bekaa where both WUA members and non-members often defect generating water stresses and where an external sanctioning system is then applied (design principle 5.).

When total water availability significantly drops, the WUAs initially set up in period 1 would move to phase 2 ("water stress"), the WUAs already in place in period 2

would record a worsening situation, whereas the WUAs starting in period 3 ("sanction") would shift to period 4 ("more water stress"). The game theory indicates that the reduction in water availability, and the resulting risk generation for lower incomes, can easily increase the possibility for farmers to adopt free-riding behaviours. More specifically, the game structure shows that, in period 2, players reach a prisoner dilemma stage: they could be better off if they cooperated, but for several reasons (mistrust, lack of communication, bargaining costs, etc.), they defect by adopting a dominant strategy and reaching a Nash equilibrium, but not a Pareto-optimal solution.

Those Lebanese WUAs that explicitly foresee the adoption of a graduated sanctioning scheme could apply it in this second phase: the introduction of a fine would reduce non-cooperative player's payoff in a way that free riding would no longer be the preferred option. Thus, the players could be willing to change their strategy, and the system could evolve towards period 3 where non-cooperative behaviour is no longer a dominant strategy. Without an enforcement mechanism, the WUAs could most probably undergo an exacerbation of water conflicts in the short run, whereas in the long run, if the situation is not restored, they could experience depletion of the common resource.

If water availability further decreases, due to climate change (period 4) for instance, the former sanction would not be enough high, and farmer's payoff would increase if he defected despite the penalty to pay. At this stage, the risk of free riding is higher. The game results have changed, and the game evolves into a "chicken game" structure where there are one winner and one loser. In these circumstances, the defection of both players will lead to the system collapse, and the possible consequences could be extremely severe. Therefore, an appropriate adaptation of the governance system – e.g. adequate sanction increase– is required to restore the former cooperative pattern (period 5). In similar situations, experimental studies confirmed that proper levels of disincentive have to be reached in order to promote cooperation and to prevent free-riding behaviours (Ostrom, 1992; Fehr and Gächter, 2000).

## 5. Conclusions

Water issues represent a serious challenge for Lebanese agriculture and food production and, due to climate change, they will probably and increasingly affect farmers' and established WUAs' behaviour and outcomes: their choices will play a pivotal role in influencing the resource availability and distribution. The present study provides an insight into the major enabling and constraining conditions that lead to the success and/or failure of the associations (WUAs) in implementing and adapting water governance and management schemes.

Although the country is going today through a post-conflict phase and a slow institutional reforming process, findings suggest that the Lebanese local associations – WUAs – are a potentially suitable form of participative organisation to foster a better governance and management of water resources at secondary and tertiary irrigation schemes level, and to enhance Lebanese farmers' livelihood. The results achieved through the IAD analysis highlight that the WUA success depends on the ties among community members and on the understanding of the mutual benefits that joint governance and management as well as cooperation can produce. Information and awareness raising campaign are also playing an important role to ensure the farmers' commitment to WUAs rules. However, different and new governance initiatives and actions still need to be investigated in order to boost farmers' capacity building, especially considering that so far, NGOs, International Donors and aware Lebanese officials have been the driving forces in the WUAs establishment.

Nevertheless, the Lebanese local institutions are fragile and exposed to failure, as they do not pursue relevant design principles. The lack of institutional recognition and of subsidiarity, the uncertainty of operational (supervised) autonomy, and the exclusion from the decision-making process for irrigation water governance and management at different levels, undermine their robustness. Given the lack of a specific regulation and the shortfall in the institutional reform, each WUA has to decide its own institutional setting, mainly to act as a cooperative, while leaving great uncertainty over future arrangements and operational discretion. Furthermore, some of the operational rules and water allocation agreements date back to the ottoman period and no one is seriously questioning them. This might limit the WUAs capacity to adapt to changing conditions because of intrinsic stiffness. However, where WUAs are operating and filling the institutional gaps, irrigation water use manages to meet producers' requirements. Poor coordination among central and local bodies, lack of governance, and mismanagement in Lebanese rural areas appear to be some of the main causes behind water scarcity. Finally, WUAs should be given the possibility to change their statutory and operational rules, especially with regard to their enforcement systems, since an adaptive governance measure could be envisaged so as to favour their robustness and increase the capacity to cope with expected water scarcity and to avoid heavy consequences.

All in all, WUAs represent a vibrant environment which need a clear normative recognition (Anderies, 2004), and which should evolve as local institutions capable of providing governance frameworks, incentives and knowledge for farmers in order to foster their ability to cooperate and, in the meantime, to reach a higher degree of competitiveness. However, the assumptions and the results of this study suggest that further research and quantitative assessment are needed. In particular, additional analysis is required to explore the role that local governance solutions, incentive schemes, organizational, technological and social innovations can play when confronted with changing economic conditions and environmental challenges, and to evaluate the resulting impacts on the local institution robustness and resilience and on farmers' behaviours and awareness.

## References


Anderies, J.M., Janssen, M.A. and Ostrom, E., 2004. A framework to analyze the robustness of social-ecological systems from an institutional perspective. *Ecology and Society,* 9: pp.1-18.

Anderies J.M. and Janssen M.A., 2011. The fragility of robust social-ecological systems. *Global Environmental Change,* 21(4): pp.1153-1156.

Anderies, J.M., Janssen, M.A., Lee A. and, Wasserman H., 2013. Environmental variability and collective action: Experimental insights from an irrigation game. *Ecological Economics*, 93:, pp. 166-176.

Ansink, E. and Ruijs, A., 2008. Climate change and the stability of water allocation agreements. *Environmental and Resource Economics,* 41 (2): pp.249-266.

Baggio, J.A., Barnett, A., Perez-Ibarra, I., Brady, U., Ratajczyk, E., Rollins, N., Rubiños, C., Shin, H. C., Yu, D. J., Aggarwal, R., Anderies, J. M., Janssen, M. A., 2014. *The puzzle of good governance: Putting the pieces together through the lens of Ostrom's Design Principles*. CSID Working Paper Series, 2014-008.

Bastakoti, R.C. and Shivakoti, G.P., 2009. *Context and institutions in irrigation management : Applicability of design principles*. Paper presented at Workshop on the Workshop 4, panel "Water and Design Principles" at Indiana University, in June 2009.

Blaikie, P., 2006. Is small really beautiful? Community-based natural resource management in Malawi and Botswana. *World Development,* 34 (11): pp. 1942-1957.

Bou-Zeid, E. and El-Fadel M., 2002. Climate change and water resources in Lebanon and the Middle East. *Journal of Water Resources Planning and Management,* 128 (5): pp. 343-355.

Comair, F., 2007. Water Sector sector in Lebanon: an operational framework for undertaking legislative and institutional reforms, New York: UN. ESCWA, New York.

Cox, M., Arnold, G. and Tomas, S.V., 2009. *Ddesign principles are not blue prints, but are they robust? A Metameta-analysis of 112 sStudies*. Lincoln Institute of Land Policy. Working Paper.

El Chami, D. and Karaa, K., 2012. New legislation for Water User Associations (WUA): Increasing sustainability in irrigation project implementation in Lebanon. *Water Utility Journal,* (4): pp. 33-38.

El-Fadel, M., Maroun, R. and Ghanimeh, S., 2012. IWRM for climate change adaptation in the MENA region. *In: Proceedings of the IWA World Congress on water, climate and energy.* Dublin, Ireland.

El-Fadel, M., Zeinati, M. and Jamali, D., 2000. Water Resources resources in Lebanon: characterization, water balance and constraints. *International Journal of Water Resources Development*, 16 (4): pp. 615-638.

FAO, 2014. AQUASTAT. *Report Lebanon Aquastat* .http://www.fao.org/nr/water/aquastat/countries_regions/lbn/index.stm, *Report Lebanon Aquastat,*. Food and Agriculture organization of the United Nations (FAO).

Fehr, E. and Gächter, S., 2000. Cooperation and punishment in public goods. *The American Economic Review,* 90 (4): pp. 980-994.

Hardin, G., 1968. The tragedy of the commons. *Science*, 162 (June): , pp. 1243-1248.

Gentle, P., Thwaites, R., Race, D. and Alexander, K., 2013. Changing role of local institutions to enable individual and collective actions for adapting to climate change. IASC2013 Abstracts. In: *Tthe 14th Global Conference of the International Association for the Study of the Commons*. IASC, Japan. p. 40.

Gharios, G., 2009. *Lebanese Waterwayswaterways. Strengthening I-WRM through WUAs in irrigation schemes*. Wageningen Univerity. Unpublished MSc. Thesis, Wageningen Univerity.

Gibson, C., McKean, M. and Ostrom, E., 2000. *People and Forestsforests: Communities, iInstitutions, and gGovernance*. Cambridge, MA: MIT Press.

Gustafsson, M., Biel, A. and Gärling, T., 2000. Egoism bias in social dilemmas with resource uncertainty. *Group Processes and Intergroup Relations,* 3: pp. 351-365.

IPCC, 2014. *Climate Change 2014: Impacts, adaptation, and vulnerability. Part A: Global and sectoral aspects*. Contribution of Working g-Group II to the Fifth Assessment Report of the Intergovernmental Panel on climate change. Cambridge: Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1132.

Janssen, M.A. and Anderies, J.M., 2013. *Multi-method approach to study robustness of social-ecological systems: the case of small-scale irrigation systems*. CSID. Working paper series, 2013-001.

Kim, K., 2004. *The evolution of self-governance in Korean irrigation systems: with reference to the farmers' self-governing model district program*. Paper presented at the Workshop on Political Theory and Policy Analysis, May 3-5.

Lamaddalena, N. and Khandra, R., 2012. *Regional assessment - water users' associations in the swim-sm partner countries*. WUAs Expert Regional Workshop, Athens, Greece, 23-24 April, 2012, http://www.swim-sm.eu/files/ Regional_Assessment_on_WUAs_EN.pdf, 2012, Athens.

Madani, K., 2010. Game theory and water resources. *Journal of Hydrology*, 381(3-4): , pp. 225-238.

Madani, K. and Dinar, A., 2012. Cooperative institutions for sustainable common pool resource management: Application to groundwater. *Water Resources Research,* 48 (9): W09553

MoA, FAO, Cooperazione Italiana allo Sviluppo, 2012. *Résultats globaux du module de base du recensement de l'agriculture 2010.* Beirut: Ministère de l'Agriculture Libanais, Beirut.

MoE/UNDP/ECODIT, 2011. *State and trends of the Lebanese Environment*. Beirut.

Mosse, D., 1997. The symbolic making of a common property resource: history, ecology and locality in a tank-irrigated landscape in South India. *Development and Change,* 28: pp.467-504.

Nash, J.F., 1950, "Equilibrium points in n-person games". In: *Proceedings of the National Academy of Science of the USA,* 36: pp. 48-49.

NPMPLT, 2005. *National Physical Master Plan of the Lebanese Territoryterritory*. 2005. DARIAURIF, Final Report.

NWSS, 2012. *National water sector strategy* .2012. Lebanon: Ministry of Environment and Water, Lebanon

Ostrom, E. 1992. *Crafting institutions for self- governing irrigation systems*. San Francisco: Institute for Contemporary Studies, San Francisco, California.

Ostrom, E., 1990. *Governing the Commonscommons*. The evolution of institutions for collective action.In: D. C. Alt, James E. Cambridge: North, ed. Cambridge University Press. Cambridge.

Ostrom, E., 2005. *Understanding institutional diversity*, Princeton: Princeton University Press.

Ostrom, E., 2013. Do institutions for collective action evolve? *Journal of Bioeconomics,* 16 (1): pp. 3-30.

Ostrom, E., Gardner R. and Walker, J., 1994. *Rules, games, and common-pool resources*. Ann Arbor: University of Michigan Press.

Podimata, M.V. and Yannopoulos, P.C., 2015. Evolution of game theory application in irrigation systems. ILRA *Agriculture and Agricultural Science Procedia,* 4: 271-28100 (2015) 000–000. Elsevier.

Sowers, J., Vengosh, A. and Weinthal, E., 2010. Climate change, water resources, and the politics of adaptation in the Middle East and North Africa. *Climatic Change,* 104 (3-4): pp. 599-627.

UN-Water, 2007. *Coping with water scarcity, challenge of the twenty-first century*. The Food and Agriculture Origanization (FAORome: Fao).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